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Apple Storage Investigations

Fourth Progress Report

I—JONATHAN-SPOT AND SOFT-SCALD
II—APPLE-SCALD AND INTERNAL BREAKDOWN

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
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SUMMARY—PART I.

1. The investigation deals with the development and control of Jonathan-spot, soft-scald and internal breakdown, as these are affected by maturity of the fruit, cultural conditions, temperature, humidity, aeration and wrap treatments.

2. Storage temperatures had a decided influence on the development of Jonathan-spot. Higher temperatures increased the disease. 32°F. proved most satisfactory in its control.

3. More Jonathan-spot developed at the higher humidities. However, a low humidity was found impractical because of the danger of fruit becoming shriveled. A relative humidity of 80 to 90 percent is recommended.

4. Variations in the size of the fruit did not have much influence on the development of Jonathan-spot.

5. Varying the soil treatment did not give a satisfactory method of control for Jonthan-spot.

No definite relation was found between the development of Jonathan-spot and mean temperature, rainfall, and sunshine for the growing season.

7. Common storage experiments compared with cold storage conditions showed that the time of storing is important. Comparisons between results with immediate storage and delayed storage emphasize that Jonathan can be held longer in cold storage than in common storage.

8. Immediate storage in most cases gave the least amount of Jonathan-spot. This was true both for late picking and early picking.

9. Late picking generally gave the more Jonathan-spot, but the time of storing was found more important than time of picking.

10. The tendency was for Jonathan-spot to increase with delayed storage and in proportion to length of delay.

11. Jonathan-spot was more severe during the latter part of the cold storage season and increased according to the time in storage. Jonathan should, therefore, not be held in storage longer than the first of January.

12. A constant air movement of approximately seven-tenths mile per hour thruout the period of storage has given no advantage as a control measure for Jonathan-spot.

13. It was shown that Jonathan-spot cannot be controlled by employing oiled wraps.

14. Wrapping in oiled paper reduced the amount of shriveling of the skin of the apple. No deleterious effects resulted in the use of oiled wraps.

15. Maturity experiments with Jonathan showed that soft-scald is conditioned by the maturity of the fruit, when placed in cold storage. Time of storing was more important than time of picking in controlling this disease.

16. Immature Jonathan soft-scalded worse than mature Jonathan.

17. Delaying at the orchard one week usually gave more soft-scald than immediate storage, or delayed storage for periods of two or three weeks. Delay of two or three weeks gave the best control of soft-scald. Immediate storage is recommended, however, because delayed stored Jonathan are susceptible to Jonathan-spot.

18. Aerating with ventilating completely controlled soft-scald thruout one season. Aerating, or merely circulating the air within the storage room, did not give satisfactory control of the disease.

19. Oiled wraps did not control soft-scald on Jonathan.

20. Soft-scald occurred early in the storage season. It made practically no development after the normal cold storage season of Jonathan was past. Soft-scald was considerably influenced by maturity conditions in the early storage period.

21. Internal breakdown was never a factor in the storage experiments where Iowa Jonathan were used.

APPLE STORAGE INVESTIGATIONS

Fourth Progress Report

I -JONATHAN-SPOT AND SOFT-SCALD
II-APPLE-SCALD AND INTERNAL BREAKDOWN

By H. H. Plagge and T. J. Maney

This is the fourth report* of the apple storage investigations begun in 1906 by the Pomology Section of the Iowa Agricultural Experiment Station. The report embodies the results of investigations dealing mainly with the development and control of such storage diseases as Jonathan-spot, apple-scald and internal breakdown. The investigations are divided into two parts. Part I deals with the development and control of the storage diseases, Jonathan-spot and soft-scald on the Jonathan apple. Part II includes studies on the development and control of apple-scald and internal breakdown and the effect of certain odorous substances on apples.

The report embodies the results of investigations on the keeping quality of apples in storage as affected by varying treatments in the orchard, as time of picking, time of storing and soil cultural methods. Various storage conditions such as temperature, humidity, and aeration have been considered. Particular attention has been given to different types of apple wraps. The keeping quality of Jonathan apples has been compared in cold and common storage.

MATERIALS AND METHODS

The cold storage apparatus used in these experiments was quite fully described by Whitehouse (7)** in the third report of the cold storage investigations conducted at this station. Thermographic and hygropraphic records have been obtained thruout the periods during which the experimental work has been carried out. All the experiments herein reported have been carried on with the cold storage equipment, previously described, except, when apples were placed in common storage houses to compare the latter type of storage with cold storage. In 1913 and 1914, the cold storage experiments on Jonathan-spot were carried on in the commercial cold storage plant of the Hurd Creamery Company of Council Bluffs, Iowa.

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*"Cold Storage for Iowa Grown Apples", S. A. Beach and H. J. Eustace, Bul. 108, 1909. "Cold Storage for Iowa Grown Apples", Laurenz Greene, Bul. 144, 1913. Cold Storage for Iowa Apples", W. E. Whitehouse, Bul. 192, 1919.

The authors have compiled and have made use of data collected thru a series of years and therefore give grateful acknowledgement to the past and present members of the Pomology Section staff who have had a part in the work of the Cold Storage Project. Included are Laurenz Greene, W. E. Whitehouse, H. L. Lantz, H. E. Nichols, T. R. Hall, W. C. Calvert, E. B. Lowe and W. D. Reineke.

Especial tribute is paid to the memory of the late S. A. Beach, who initiated the cold storage work at this station and whose advice was always a source of help and inspiration.

**A separate list of literature citations is given for Parts I and II, respectively.

In the cold storage rooms of the Pomology Section, a temperature of 32°F. and a relative humidity ranging from 85 to 90 percent were maintained except where other special conditions are noted.

The method used in classifying the percentages of apple-scald and Jonathan-spot as "slight", "medium" and "bad", was that described by Whitehouse (7) for apple-scald. The same basis was used for classifying the severity of soft-scald. The range of percentage for these classes for Jonathan-spot is 0 to 25 percent, "slight-spot"; 25 to 50 percent, "medium-spot"; 50 to 100 percent, "bad-spot". In some cases the amount of "total-spot" is given consideration. The total-spot indicates the total number of apples having Jonathan-spot regardless of the severity of the disease. Classifying into classes, slight, medium and bad, gives a better indication of the amount of Jonathan-spot as it shows relative area spotted as compared to the total area subject to spot.

The varieties principally used were Grimes, Jonathan, Rome and Arkansas. In most cases, the fruit was grown and packed at the State Experimental Orchard at Council Bluffs, Iowa, except in 1921-22 when western grown apples were used. In 1915-16-17, the Jonathan apples for soil cultural treatments were obtained from the orchard of Worth Brothers* at Mondamin, Iowa. The fruit from the state orchard, in most instances, was picked from trees planted in the year 1892. These were growing in clover sod plots. It was packed in standard apple boxes and shipped by express to Ames, Iowa. Approximately 24 hours elapsed between the time of shipping and storing.

For the season of 1919-20, the apples were packed as an orchard run grade, using sound fruit. In 1920-21 and 1922-23, strictly extra fancy packs were used. In 1921-22, due to a crop failure in Iowa, Jonathans from New Plymouth, Idaho, were used. The Grimes that year came from the Wenatchee district, Washington, and the Rome from the Grand Ronde valley district, Oregon. The Grimes were grown in several different orchards, were shipped under refrigeration and were in the car eleven days. The Jonathan came from several orchards, were shipped under ventilation without refrigeration and were en-route seven days. The Rome apples were grown under lightly irrigated conditions in one orchard, were shipped under ventilation and were in the car ten days. The Grimes and Jonathan were given the amount of irrigation customary for the particular section. Upon arrival at Ames, these apples were immediately unwrapped. They were then rewrapped and placed in cold storage according to the various treatments outlined.

*Grateful acknowledgement is given to M. J. and E. O. Worth for their generous cooperation in carrying out this part of the work.

Commercial quantities of fruit were used in the various tests, which is in accordance with previous experiments reported by this station. The apples were usually examined twice during each season. Exceptions to this were in 1921-22, when the variety, Rome, was examined once, and in 1922-23, when all the apples were given one examination. The examinations of the fruit each year were made by the writers or by persons assisting under their direct supervision. The data secured are, therefore, comparable from year to year. The dates of the different pickings ranged thruout the normal picking season for the variety. These dates were usually four or five days apart.

The plan adopted each year provided for the picking in series of four boxes each; storing immediately one box of each series at time of picking and holding the other three boxes at the packing houses, one, two and three weeks, respectively, before storing. The temperature of the packing shed was recorded thruout the period of delayed storage. The number of pickings of Grimes during each season was in 1919, four; 1920, six; 1922, five. In 1922, there were three different pickings of Arkansas. The number of different pickings of Jonathan each season was 1919, five; 1920, six; 1922, five.

I. JONATHAN-SPOT AND SOFT-SCALD

JONATHAN-SPOT

One of the most troublesome storage diseases of the Jonathan apple is Jonathan-spot. It is more often associated with the Jonathan because it occurs most frequently and reaches a high stage of development on this variety. It sometimes occurs also on Rome Beauty, King David and Esopus. Jonathan-spot is found on apples grown under many different conditions and locations. It may occur on fruit on the tree or on windfalls. In other instances, it does not occur until very late in the storage season. Jonathan-spot does not occur so often or so severely on the more poorly colored apples, but is more likely to make its appearance on deeply colored specimens. Those specimens which have the darkest red color and which have the highest quality are usually the most severely affected. The disease usually appears after the apples have been placed in storage.

Jonathan-spot, as shown in figs. 1 and 2, is manifested by dark colored, sometimes almost black superficial spots, ranging from a greenish tinge on lighter colored surfaces to a blackish color on the deeply blushed areas. The spots are usually roundish, but may be confluent and may form irregular patches. These spots vary from about one-sixteenth to one-fourth inch in diameter

Fig. 1. Jonathon-spot. These three specimens show peculiar patterns often found. Specimen on the extreme left shows a band of spot around a sun-scalded area.

as a rule and appear at first as only indistinct discolorations of the skin.

The darker side of the apple is usually more likely to become affected. Sometimes the spots occur in a circular band around an area which has been slightly sun-scalded. Often the spots occur in a mass, in one small area, resembling one large spot. Several of these larger or confluent spots may occur on a single apple in patches. Jonathan-spot frequently manifests itself around a bruised area in a band more or less circular in shape, following the margin of the bruise. The spotting detracts from the appearance and lessens the commercial value of the fruit. McAlpine (4) has stated that the spot usually extends *all* over the calyx and middle of the apple, while the stem end is comparatively free. Our observations have led us to believe that Jonathan-spot more often develops around the stem end of the fruit rather than the calyx end.

Fruit dealers estimate that at least 50 percent of all Jonathan develop spot while in storage. Experimental data show this estimate to be rather conservative. Altho Jonathan-spot does not materially affect the immediate culinary or dessert qualities of the apple, it does detract from the appearance of the fruit on the market. Brooks and Cooley (1) have shown that apples affected with Jonathan-spot are especially susceptible to infection with species of Alternaria. They also state that their observations indicate fungi are not present in the early stages of the disease, but that the spots often served as points for infection by apple fungi. While our observations indicate that sound Jonathan apples held at a storage temperature of 32°F. are not very often affected by the apple rot fungi, the danger from these diseases probably increases when the apples are taken out of cold storage and exposed to warmer temperatures.

INFLUENCE OF TEMPERATURE ON JONATHAN-SPOT DEVELOPMENT

Scott and Roberts (6), while investigating Jonathan-spot, have found it developing rapidly in a moderately cool basement. In 15 days, 40 percent developed on a certain lot, but on a duplicate lot in cold storage, only 10.5 percent developed in three months. Brooks and Cooley (1) have reported that Jonathan-spot developed very rapidly between 10° and 15°C., but was checked at 5° or 0° and 30°C. A fluctuating temperature between 5° and 25°C. gave no harmful effect in regard to Jonathan-spot development.

The relation of temperature to Jonathan-spot has been investigated at this station during the seasons of 1915-16, 1916-17 and 1917-18. In 1915-16, comparable lots of Jonathan apples were picked at the State Experimental Orchard, Council Bluffs, Iowa, and stored at 32°, 36°, and 40°F. In February it was found that 3.53, 5.08 and 7.1 percent of Jonathan-spot was present, respectively.

In 1916-17 an experiment with two lots of six boxes each of 175 Jonathan apples to each box, were stored in cold storage at 32° and 40°F., respectively. The same experiment was carried out in 1917-18. The results for the two seasons noted in April are given in table I.

TABLE I. EFFECT OF TEMPERATURE ON JONATHAN-SPOT DEVELOPMENT

Year	32°F.		40°F.	
	Bad spot	Total spot	Bad spot	Total spot
1916-17	16.5	78.0	32.1	77.4
1917-18	10.6	63.0	21.8	63.4

Practically the same amount of total spot developed at both temperatures, but the amount of bad spot found at 40°F. was twice that at 32°F.

Fig. 2. Jonathan-spot. The three specimens are typically spotted.

In 1917-18 six boxes of Jonathan of 150 apples each were placed in commercial cold storage at 33°F., at the same time six boxes of the same sized apples were placed in each of the common storage houses at the orchards of W. S. Keeline, Council Bluffs; D. W. Lotspiech, Woodbine; C. H. Deur, Missouri Valley and at the Iowa State Hospital, Clarinda, Iowa. The temperatures of these storage houses which were recorded on thermographs ranged between 40° and 50°F. until January and between 32° and 40°F. from January until March. An examination on February 1, 1918, showed 31.3 percent of Jonathan-spot on those apples at 33°F. in cold storage and 54 percent on those held in the common storage houses.

If the apples in the respective lots were of comparable maturity, the above data show that the storage temperature has a marked influence on the development of Jonathan-spot. These results show that a slight increase in temperature is likely to result in a large increase in Jonathan-spot.

EFFECT OF HUMIDITY ON JONATHAN-SPOT

Brooks and Cooley (1) have found less spot developing on Jonathan apples stored in open containers, in a relative humidity of 70 percent, than on a similar lot of fruit stored in moist chambers at the same temperature. There was a good circulation of air in the open containers, while there was practically no circulation in the closed moist chambers, which suggests that the variations were due to differences in aeration rather than to the amount of humidity.

In 1916-17 six boxes of 125 apples each were stored at 30°F. in a relative humidity of 60 to 70 percent until April 18, 1917. These developed 73.2 prcent total spot, while six comparable boxes under the same conditions except for a higher humidity, that of 80 to 90 percent, developed 87.8 percent of total spot. In a similar experiment the following year, by March 20, 59 percent developed at 60 to 70 percent humidity while 76.7 percent developed at an 80 to 90 percent humidity. The tendency seems to be for more spot to develop at higher humidities.

Fifty sound, well colored Jonathon apples were wrapped in moist blotting paper and exposed to a room temperature of 80°F. At the end of 72 hours all the apples so treated were badly spotted. A check lot showed no spot.

In 1915 an interesting observation along this line was made in a commercial orchard. During a period of expected cold weather, several hundred two bushel crates of Jonathan apples were stacked together and covered with corn stalks on the top and sides. When the apples were examined at the end of four

days the humidity beneath the corn stalks was very high and the fruit had developed bad spot on nearly every specimen.

INFLUENCE OF SIZE ON JONATHAN-SPOT

Apples packed 150 to the box in a low humidity and at 40°F. showed more spot development than apples of 175 to the box at a high humidity and the same temperature. Jonathan apples of 175 to a box under a high humidity at 32°F. developed the same amount of total spot as did fruit of comparable size at 40°F., but there was twice as much "bad" spot at the latter temperature.

The effect of the size of the apple on the susceptibility to Jonathan-spot was observed thruout the seasons of 1913 to 1922, inclusive, except for the seasons of 1918-19 and 1919-20. The examinations were made in March or April each of the years. The figures are given on a percentage basis. The number of boxes used varied from 1 to 27 for each size given.

TABLE II. INFLUENCE OF SIZE ON JONATHAN-SPOT DEVELOPMENT.

	Number of apples to the box							
Season	113	125	138	150	163	175	188	200
1913-14	....	....	46.7	....	7.1	10.5	....	....
1914-15	58.0	28.0	31.9	42.0	41.1	40.0	....	33.0
1915-16	....	....	....	46.0	....	48.3	40.3	37.5
1916-17	....	87.8	....	74.9	....	78.0	....	....
1917-18	....	76.7	....	63.3	....	63.0	....	....
1920-21	....	33.6	22.3	39.6	29.9	32.3	34.7	....
1921-22	....	11.5	12.2	7.8	10.3	4.3	....	....
1922-23	....	3.7	4.5	2.3	5.6	5.7	9.7	....

One year's results are not comparable with those of another year, but the results for the different sizes of each year are comparable. Some seasons the larger sizes were only slightly more susceptible to Jonathan-spot, but other seasons the smaller sizes were more susceptible. The results show that size is not an important factor in control of Jonathan-spot.

INFLUENCE OF VARIOUS CULTURAL METHODS ON JONATHAN-SPOT DEVELOPMENT

To determine whether there was a relation between soil treatment and the amount of Jonathan-spot, observations were made during the seasons, 1913 to 1918, on fruit grown at the state orchard. The apples in the State Experimental Orchard at Council Bluffs are grown under four types of soil treatment. The orchard is divided into six plots; two are maintained with a clover sod; two cultivated during the growing season until late July, then seeded to a cover crop; one clean cultivated during the entire season and one is maintained in bluegrass sod. The clover and bluegrass sod plots are maintained thruout each year. The cover crop treatment consists in clean cultivating until the last of July, when a crop such as rye, oats, vetch, or

buckwheat is sown for a winter cover and then turned under the following spring. These different practices of soil management began in 1910 so that three growing seasons passed before the experiments on Jonathan-spot herein reported were undertaken. Jonathan apples were picked from trees grown under each of these systems of culture.

Table III gives the percentage of total Jonathan-spot which developed on apples picked from trees in each soil treatment plot. These figures represent the average of one to three boxes during the first two years of the work and three to five boxes during the last three years. The data show the amount of spot for either March or April for each season.

TABLE III. INFLUENCE OF CULTURE ON JONATHAN-SPOT DEVELOPMENT

Treatment	Percentage of total Jonathan-spot				
	1913 1914	1914 1915	1915 1916	1916 1917	1917 1918
Clover sod	6.3	28.1	35.9	88.0	56.0
Cover crop	6.3	46.0	50.0	71.0	66.8
Clean cultivation	1.2	55.3	51.0	78.1	68.6
Bluegrass sod	0.0	83.0	39.8	82.6	81.3

There was no consistent difference in the amount of spot on the fruit from the various plots. The results have so varied that it is safe to conclude that soil treatment is not important in development or control of Jonathan-spot.

In order to consider the degree of spotting, a record is given for three years showing the amount of bad-spot, the form easily seen by the consumer. These apples were held in storage at 34°F. until February and thereafter at 32°F. until March or April, during the years indicated. The data in table IV show these results and give a more accurate knowledge of the extent of the development of Jonathan-spot. Here again, there is no agreement in the data presented.

TABLE IV. INFLUENCE OF SOIL TREATMENT ON JONATHAN-SPOT DEVELOPMENT

Treatment	Percentage of bad spot		
	1915–16	1916–17	1917–18
Clover sod	13.8	19.0	7.3
Cover crop	26.8	13.3	15.3
Clean cultivation	24.5	7.8	9.3
Bluegrass sod	21.2	10.4	18.6

Effect of soil conditions upon Jonathan-spot was further investigated in the orchard of M. G. Worth and E. O. Worth, Mondamin, Iowa, during the seasons of 1915, 1916, and 1917. This orchard is located in the Marshall Silt Loam type of the Missouri Loess area. The soil is similar to that of the State Experimental Orchard at Council Bluffs. Some of the trees are located on washed ridges from which the darker surface top soil has been long removed. These trees on the washed areas

are not as vigorous or productive as those on the darker colored slope soils and ridges. Apples were picked from trees growing under the varying conditions present in this orchard to note the effect on the amount of Jonathan-spot development.

The exact conditions under which each of the lots of trees were growing are given in table V, with the corresponding amount of Jonathan-spot development for each treatment and for the three seasons during which observations were made.

The amount of the disease varied considerably from year to year and it is not possible to interpret these data as being in favor of any one of the various treatments as a method of control for Jonathan-spot. While more Jonathan-spot occurred in 1915 on the apples from trees growing on the thin soils of the washed ridges, the opposite was true for 1916 and 1917 and the apples from trees which had made the better growth had the

TABLE V. JONATHAN-SPOT AS AFFECTED BY SOIL CONDITIONS IN A COMMERCIAL ORCHARD

Lot no.	Description of orchard plot treatments. Worth Bros. Orchard, Mondamin, Iowa.	Total percentage of Jonathan-spotted apples					
		1915-16		1916-17		1917-18	
		Exam'd Jan. 31 1916	Exam'd May 20 1916	Exam'd Apr. 17 1917	Exam'd May 17 1917	Exam'd Jan. 14 1918	Exam'd April 16 1918
1.	Young trees planted in 1909; in clover sod 1914 and 1915; fruit well developed but not over size	21.3	68.7	74.4	81.3	39.0	40.0
2.	Trees planted in 1899; orchard cultivated when young; in clover sod until 1913; intensive cultivation to summer of 1915, following later with heavy growth of foxtail grass; trees were making excellent terminal growth	17.9	61.9	67.4	75.8	26.0	59.7
3.	Orchard planted in 1899; cultivated when young; in alfalfa sod up to 1909; intensive cultivation to summer of 1915 followed with heavy growth of foxtail grass; trees making excellent growth	27.4	72.6	93.5	93.9	54.7	94.0
4.	Trees growing on washed ridges from which the darker surface soil had been long removed; no cultivation previous to experiment; light growth of foxtail grass present; trees with very poor terminal growth	43.0	96.7	63.0	63.5	22.0	60.0
5.	Fruit picked from trees planted in 1899; deficient in foliage; cultivation not so intensive as lots two and three; seeded to clover in 1915. Fruit used came from branches making no apparent terminal growth and having very scant foliage	45.0	91.2	....	....	....	....
6.	Fruit used was an orchard run pack, taken from all of the above lots	....	....	58.7	59.2	23.0	49.0

most spot. Fruit from the younger trees did not appear to be more susceptible to Jonathan-spot.

The influence of the amount of color and degree of maturity on the development of Jonathan-spot is probably a more important consideration than soil cultural treatment.

In 1917-18, a comparison of western grown, irrigated Jonathan apples with Iowa grown apples from a sod plot at the state orchard was made with respect to their susceptibility to spot. The irrigated fruit from Wenatchee orchards had received the normal amount of irrigation, while the non-irrigated apples from Iowa came from a sod cultural plot which showed some effects of drought. Two boxes from each source were used. The following results were obtained in this test:

TABLE VI. EFFECT OF SOIL MOISTURE ON JONATHAN-SPOT

Treatment	Date of storing	Percentage of total spotted apples	
		Condition	
		Jan. 1	April 10.
Irrigated	Oct. 10, 1917	10.5	55.2
Not irrigated	Oct. 10, 1917	18.8	56.1

There is little difference here to indicate that irrigation materially affects the amount of spot development. Brooks and Fisher (2) found that the contrasts in the amount of Jonathan-spot between different irrigated plots receiving various amounts of irrigation was not very consistent, altho, in general, heavy irrigation slightly favored the disease.

A COMPARISON OF METEOROLOGICAL DATA WITH THE OCCURRENCE OF JONATHAN-SPOT

An attempt was made to correlate the amount of Jonathan-spot occurring for the years 1915 to 1922, with the amount of rainfall, the temperature and the amount of sunshine for this same period. Meteorological reports from the United States Department of Agriculture weather bureau station at Omaha, Nebraska, and records from the State Experimental Orchard, Council Bluffs, Iowa, were consulted. The data for the growing season only, from May until October, inclusive, were considered.

In 1915, the greatest rainfall and the largest amount of Jonathan-spot occurred simultaneously; no relation between the two could be seen for the other years. In fact, the amount of rainfall for the other years did not vary sufficiently to be of much significance.

The data on temperature in relation to Jonathan-spot show little or no relationship. In 1922, the mean temperature from May to October was the highest, but the least amount of spot

occurred this year. The seasons 1915 and 1917 have about the same mean temperature and were the two coolest years, but considerable Jonathan-spot occurred these years, more occurring in 1915 than in any other year. Almost three times as much spot occurred in 1920 as in 1919, but the two seasons had practically the same mean temperature. The two years 1916 and 1917 had about the same amount of this disease, but the former season had a higher mean temperature.

The records for the amount of sunlight and the amount of Jonathan-spot show some slight relationship. The seasons with the greatest amount of sunshine show a decreased amount of Jonathan-spot.

COMMON STORAGE AND COLD STORAGE FOR JONATHAN APPLES

Jonathan apples were placed in common storage houses while duplicate lots were placed in cold storage at 32°F. thruout the seasons 1915-16 and 1917-18. The temperature of the common storage houses averaged around 45°F. the first part of the season and 37°F. the last part. In practically every case, much more Jonathan-spot developed on the apples in common storage.

In experiments dealing with common storage and cold storage conditions or with other temperature relation studies with apples, the question of maturity always must enter in. We know from Van't Hoff's law that respiration and the ripening processes increase about two to three times with every 10°C. increase in temperature (within certain limits).

We should, therefore, expect cold storage apples to be less mature than common stored apples, other conditions being the same. Also, common storage fruit ripens much more rapidly than cold storage apples. With "delayed stored" cold storage apples, just what length of delay would result in a maturity comparable to, "immediately stored", common storage apples, would be usually difficult to ascertain. But there is a probability that such a condition could exist. In an investigation on cold storage fruit and on fruit in common storage, the initial maturity at time of picking, time of storing, and exact temperatures maintained thruout for each kind of storage are important, since all of these effect the maturity and, therefore, the amount of Jonathan-spot development.

If the relationship between maturity and the amount of Jonathan-spot is accepted, then there must be a time when delayed stored, cold storage Jonathan apples will spot to about the same degree as do immediate stored common stored fruit. The results obtained in 1917 (table VII) bear this out. Jonathan-spot was more abundant on January 1, in most all cases on

the cold storage fruit, but in April the opposite was true and common stored fruit had developed more spot in all comparisons.

THE EFFECT OF MATURITY ON JONATHAN-SPOT DEVELOPMENT

There has been a diversity of opinion as to the role that maturity plays in Jonathan-spot development. Ramsay, McKay, Markell, and Bird (5) reported that Jonathan-spot developed more readily with apples which had been given delayed storage treatment, as compared with apples which had been stored immediately after picking. They also indicated that the time of picking had little or no influence upon Jonathan-spot occurrence. Brooks and Cooley (1) found more spot developing on the greener more immature Jonathan, but they stated it did not necessarily follow that the spots developing under orchard conditions would obey the same law.

In 1917 maturity as it effects Jonathan-spot development was studied from two standpoints: delayed storage versus immediate storage, and time of picking the fruit. Twelve boxes of Jonathan were picked early and 12 were picked at the normal harvest period for this variety. Three boxes of each picking were placed immediately in cold storage at a temperature of 32°F. and three in common storage, which averaged 40° to 45°F. during the season. The other boxes were held in the packing shed at the orchard for two weeks before storing under the same two temperatures. The apples used in this work were small (188 to the box). The early picked fruit was immature and had less red color than the normally picked fruit. The latter was well colored and mature. The following table shows the development of Jonathan-spot, both in common and in cold storage.

TABLE VII. INFLUENCE OF MATURITY ON JONATHAN-SPOT DEVELOPMENT. 1917-18.

	Cold storage 32°F.		Common storage 40-45°F.	
	Stored immediately	Delayed 2 weeks	Stored immediately	Delayed 2 weeks
	Percentage of bad spot, Jan. 1, 1918.			
Early picked	1.0	0.3	2.3	2.0
Normal picked	1.0	1.3	1.6	0.3
	Percentage of total spot, Jan. 1, 1918.			
Early picked	22.0	22.0	1.9	17.0
Normal picked	64.3	52.0	37.6	30.6
	Percentage of bad spot, April 10, 1918.			
Early picked	1.5	4.3	10.0	5.7
Normal picked	8.0	11.6	11.6	15.0
	Percentage of total spot, April 10, 1918.			
Early picked	18.5	26.0	58.3	41.6
Normal picked	70.0	71.0	84.3	89.3

Jonathan-spot developed to a greater extent on apples which were well colored and matured than on apples picked earlier, which were green, immature, and had only a small amount of red color. Delaying the storage of any one picking for two weeks did not have a decided influence on the development of Jonathan-spot, as judged by the percentage of bad spot.

In 1915-16-17, the effect of the time of picking on Jonathan-spot development was studied. In 1915, apples were picked both at normal picking time and two weeks later. In 1916 and 1917, early picking was compared with normal picking. Thruout the three years, Jonathan-spot developed less on the earlier picked fruit.

Jonathan apples do not mature uniformly over the trees. Tnis may be due to the differences in the amount of light received by individual specimens, to differences in relative positions upon the tree, or to morphological conditions which result in physiological variations. To note the influence of these differences in ripening on the development of Jonathan-spot, two boxes of Jonathan apples were picked on the same day; one from the top and the other from the bottom of the tree. The apples were packed as they came from the tree, size and color not being considered. They were stored at 40°F. on October 6, 1915. When examined late in May, the apples picked at the top of the tree had 36.5 percent of bad spot. Those picked at the bottom had only 7.1 percent. On a total spot basis, those picked at the top had 64.0 percent while those picked at the bottom had only 23.6 percent. In this case again, the apples at the top of the tree with considerable more color had developed more Jonathan-spot.

The results of this study point to the state of maturity as the important influence in retarding Jonathan-spot development. Immaturity and poor color in Jonathan are closely related. The factors influencing color undoubtedly are closely associated with occurrence of Jonathan-spot.

In 1919, Jonathan known to be at different stages of maturity as determined by the time of picking, time of storing, by color of fruit and seeds, and by ease of picking, was used in an experiment. A constant temperature and humidity were maintained thruout the test. The picking season was arranged according to the condition and rate of ripening of the fruit. The relation of maturity to spot development during the season 1919-20 is shown in table VIII. In general, the later the fruit was stored after picking the more abundant was Jonathan-spot. In this test the apples were of orchard run grade, and not uniform in color or size. This might account for the variations noticed, especially between the different picking dates. The data are of value in that they emphasize the importance of se-

TABLE VIII. RELATION OF MATURITY TO JONATHAN-SPOT. 1919-1920.

Percentage of Jonathan-spot

Lot no.	No. Apples	No. days delayed	Condition					
			February 17			April 2		
			Slight	Medium	Bad	Slight	Medium	Bad
Apples picked Sept. 23.								
1	200	1	24.6	0.0	0.0	21.0	12.0	18.5
2	187	8	33.1	0.0	0.0	13.4	8.5	23.0
3	200	15	34.0	12.5	17.0	13.5	15.5	37.5
4	160	22	43.8	8.7	2.5	13.1	24.4	29.4
Apples picked Sept. 27								
5	200	1	2.0	0.5	0.0	8.5	6.5	1.5
6	188	8	3.7	4.7	0.0	7.9	2.1	6.5
7	202	15	4.4	0.0	0.0	10.4	3.9	1.4
8	193	22	10.6	5.7	5.1	9.3	15.5	13.4
Apples picked Oct. 2								
9	189	1	1.0	7.4	2.1	15.4	5.8	3.7
10	216	8	11.5	3.2	0.4	13.9	9.2	2.7
11	216	15	1.8	0.0	0.0	21.8	5.0	0.9
12	216	22	3.2	0.9	0.4	18.5	12.9	6.4
Apples picked Oct. 7								
13	202	1	2.9	0.0	0.0	23.8	4.9	2.9
14	195	8	1.0	0.0	0.0	11.8	4.6	0.5
15	202	15	15.8	8.9	9.9	14.3	13.4	24.8
16	202	22	7.9	4.4	10.4	12.9	12.9	12.9
Apples picked Oct. 12								
17	155	1	9.6	10.3	3.2	16.1	14.8	18.7
18	140	8	19.3	14.3	0.0	24.3	18.6	10.0
19	148	15	24.3	8.1	0.0	23.6	17.6	4.7
20	156	22	10.9	3.8	0.6	16.6	10.9	21.0

TABLE IX. EFFECT OF TIME OF PICKING AND DELAYED STORAGE ON JONATHAN SPOT—SEASON 1920-21.

Percentage of Jonathan-spot

Lot no.	No. apples	No. days delayed	Condition					
			January 28			March 28		
			Slight	Medium	Bad	Slight	Medium	Bad
Apples picked Sept. 24								
25	155	1	37.4	0.6	0.6	45.7	11.6	10.3
26	144	8	25.0	0.0	0.0	35.4	13.2	4.8
27	126	15	29.3	4.7	0.7	47.6	13.5	18.3
28	175	22	12.5	1.1	0.0	38.8	9.1	8.0
Apples picked Sept. 27								
29	138	1	23.2	0.0	0.0	56.5	10.1	5.0
30	125	8	21.6	0.0	0.0	40.8	12.8	5.6
31	138	15	47.8	7.2	0.0	31.9	23.2	26.8
32	163	22	36.2	3.6	0.0	43.5	9.8	17.8
Apples picked Oct. 1								
33	138	1	15.9	0.0	0.0	28.3	13.7	13.7
34	162	8	1.8	0.0	0.0	27.2	10.5	11.1
35	137	15	43.8	12.4	0.0	41.6	21.2	24.8
36	163	22	31.2	1.8	0.0	37.4	24.5	17.1
Apples picked Oct. 5								
37	125	1	5.6	0.0	0.0	43.2	20.0	12.0
38	139	8	44.6	9.3	0.7	18.0	22.3	42.4
39	138	15	35.5	33.3	13.1	4.3	23.2	58.7
40	125	22	44.0	38.8	16.0	7.2	12.0	72.8
Apples picked Oct. 9								
41	138	1	9.4	0.0	0.0	40.6	13.7	0.7
42	125	8	33.6	19.2	6.4	23.2	25.6	18.4
43	163	15	41.7	15.3	0.0	26.4	23.3	38.6
44	188	22	25.8	5.3	1.0	27.1	20.2	38.3
Apples picked Oct. 12								
45	134	1	0.0	0.0	0.0	41.0	6.7	2.9
46	163	8	16.5	1.8	0.6	28.8	11.3	14.1
47	163	15	56.4	11.6	5.5	29.4	9.2	44.2
48	188	22	21.2	9.5	7.9	27.6	12.7	33.5

lecting apples which are fairly uniform in size and color, in carrying out an experiment which has to do with the occurrence and control of Jonathan-spot.

The relation of the maturity of the fruit to Jonathan-spot development was further studied the following season, 1920-21. Four boxes were picked on each of six picking dates, which were three to four days apart, ranging between rather early and very late harvest dates for Jonathan. Table IX gives the data obtained in this study. Graphic comparisons based on data from the first inspection are shown in figs. 3 and 4, which show the amount of bad spot present.

January 28, there was very little or no bad spot present on the fruit which was picked on the first three dates, September 24, 27, and October 1, regardless of when they were stored. March 28, all the lots picked were affected with bad spot, but it was most abundant when storage was delayed for the longest periods.

The apples picked after the first of October and stored im-

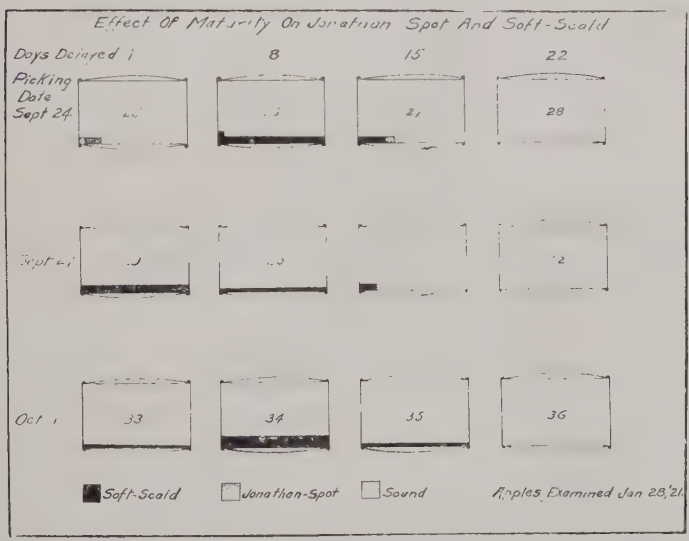

Fig. 3. Diagram showing the amount of Jonathan-spot and soft-scald on Jonathan in Jan., 1921. Dotted portions of the boxes indicate the percentage of apples affected with Jonathan-spot; black portions, the percentage of apples affected with soft-scald. All percentages are based on number of apples at the beginning of experiment. On each of the three picking dates, four boxes were picked; one for immediate storage; one for storage after one week delay; one for storage after two weeks delay; and one for storage after three weeks delay. The apples were shipped by express which increased the delay period 24 hours.

mediately had no bad spot whatever; but when storage was delayed, bad spot made its appearance. Usually the amount of spot increased in proportion to the amount of delay. These same apples, picked after the first of October, had, on March 28, much more spot than on January 28, but the proportions between the time of storing and the amount of spot present were still in evidence. It is important to notice that the amount of Jonathan-spot is liable to increase with late picking as well as with late storing.

To further note the relation of maturity to Jonathan-spot, a similar experiment was carried on during the season 1922-23. The apples were picked at five different times, between the dates September 19 and October 7. Part of the apples were wrapped in common wraps and part in oiled wraps. Each kind of wrap treatment was tried out with and without areation. For the three dates, September 23, October 4 and 7, the plan of the experiment included common wraps under both aerated

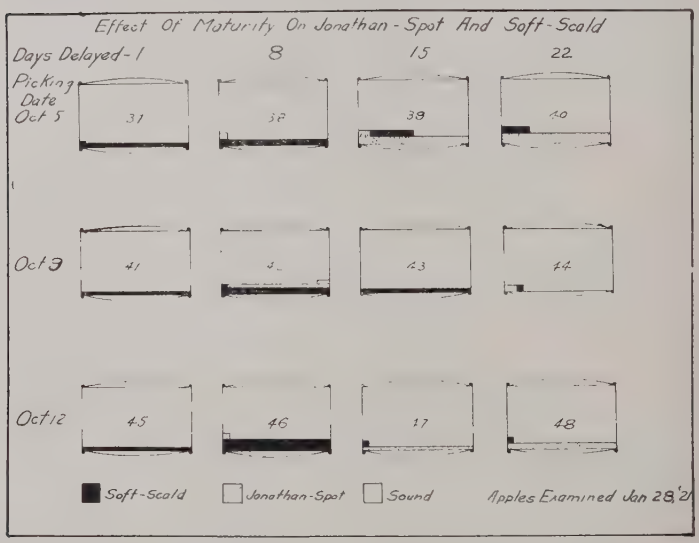

Fig. 4. Diagram showing the amount of Jonathan-spot and soft-scald on Jonathan in Jan., 1921. The dotted portions of the boxes indicate the percentage of apples affected with Jonathan-spot; the black portions the percentage of apples affected with soft-scald. All of the percentages are based on the number of apples at the beginning of the experiment. On each of the three picking dates, four boxes were picked: one for immediate storage; one for storage after one week delay; one for storage after two weeks delay, and one for storage after three weeks delay. The apples were shipped by express which increased the delay period of each shipment 24 hours.

TABLE X. RELATION OF MATURITY AND EFFECT OF AERATION AND OILED WRAPS UPON JONATHAN-SPOT.
Date inspected, March 10, 1923.

Lot No.	Date of picking	No. days delayed	No. of apples	Percentage of Jonathan-spot in boxes			
				Without aeration		With aeration	
				Common wraps	Oiled wraps	Common wraps	Oiled wraps
1	Sept. 19	1	551	0.0	0.0	0.0	0.0
2	"	8	664	0.0	0.0	0.0	0.0
3	"	15	551	2.1	13.2	8.0	2.6
4	"	22	626	11.4	13.8	8.8	7.2
5	Sept. 23	1	438	0.0	0.0	0.0	....
6	"	8	539	4.2	3.1	6.9	....
7	"	15	539	29.2	12.2	22.1	....
8	"	22	551	22.8	3.1	3.7	....
9	Sept. 28	1	525	0.0	0.0	0.0	0.0
10	"	8	556	6.7	13.1	8.0	9.4
11	"	15	525	3.9	12.6	5.6	9.6
12	"	22	639	14.8	2.2	3.6	5.3
13	Oct. 4	1	375	8.8	4.0	0.0	....
14	"	8	425	0.0	0.0	0.0	....
15	"	15	439	0.0	1.4	0.0	....
16	"	22	451	2.8	1.4	0.0	....
17	Oct. 7	1	388	0.0	4.0	0.0	....
18	"	8	400	0.0	0.0	0.0	....
19	"	15	463	4.3	2.2	0.0	....
20	"	22	500	10.6	4.0	1.7	....

and unaerated conditions, but did not include oiled wraps under aerated conditions.

Table X gives the tabular data for these tests. The plan of the experiment is shown in figs. 5 and 6 and the results are given graphically for aerated and unaerated conditions, respectively. The most significant thing brought out in this test is that in nearly all cases Jonathan-spot did not develop when the apples were stored immediately after picking, regardless of when they were picked. Apples which were picked on the earliest date, and stored immediately, or those delayed only one week, had no Jonathan-spot. At the same time, it did occur on the later stored fruit. With delayed storage, apples picked earliest and delayed, spotted worse than those picked latest and delayed, since very little spot appeared on the apples picked on the last two dates. This may partially be accounted for by weather conditions during the delayed storage period. During the period of the first three pickings the weather was very warm, whereas, after October 4 the temperature lowered considerably, with cool nights. The later picked apples, even after their delay in storage were, perhaps, not as mature as were the earlier picked fruits which were delayed in storage. The mean temperature of September was 71°F., while for October it was 59.6°F. These data suggest that the length of the period of delay before storing is more important than the actual date of picking in the development of Jonathan-spot under cold storage conditions.

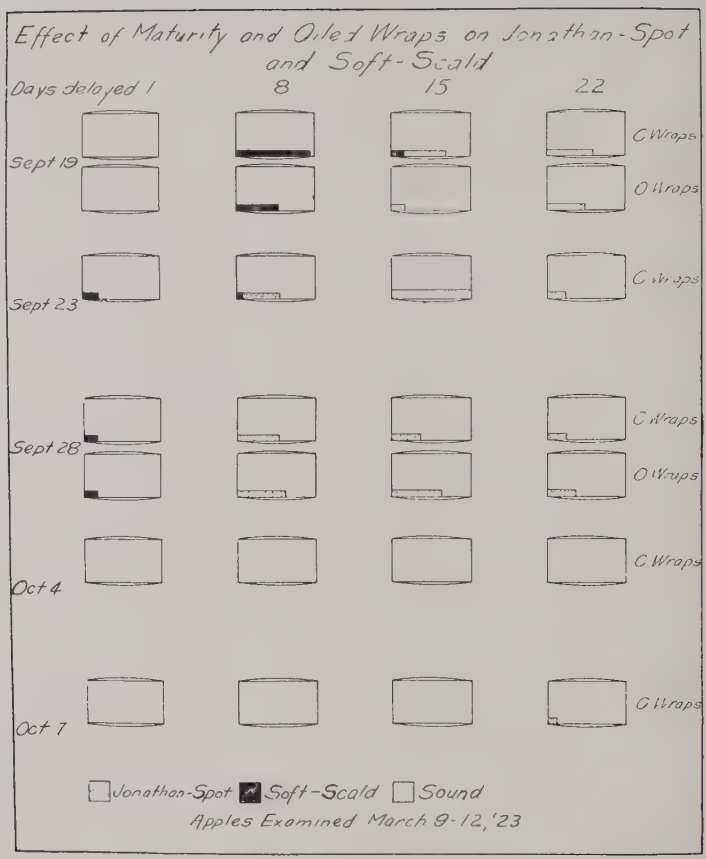

Fig. 5. Diagram showing the amount of Jonathan-spot and soft-scald on Jonathan without aeration in March, 1923. Method of indicating the percentage of apples affected with Jonathan-spot and soft-scald, and method of indicating the time of picking and time of storing, is the same as that given in figs. 3 and 4. The experiment includes a comparison of the effect of oiled wraps and common wraps, upon the development of Jonathan-spot and soft-scald. Compare with fig. 6.

Fig. 7 shows further evidence that delayed storage increases the amount of Jonathan-spot in proportion to the length of delay. This holds true especially well for the apples picked on October 5 and October 12. Fig. 4 shows similar evidence on this point.

It is well known that temperatures fluctuate widely during the apple harvest season in Iowa. This may explain why delayed storage does not always result in more spot.

JONATHAN-SPOT AS AFFECTED BY AERATION

Jonathan-spot and apple-scald have many similarities. They both occur under the same conditions of storage. Brooks and Cooley (1) have indicated that both have similar temperature, aeration and humidity responses, but that these responses are much less striking with Jonathan-spot.

Aeration experiments were conducted with Jonathan apples thruout the three storage periods of 1920-21, 1921-22, and 1922-23.

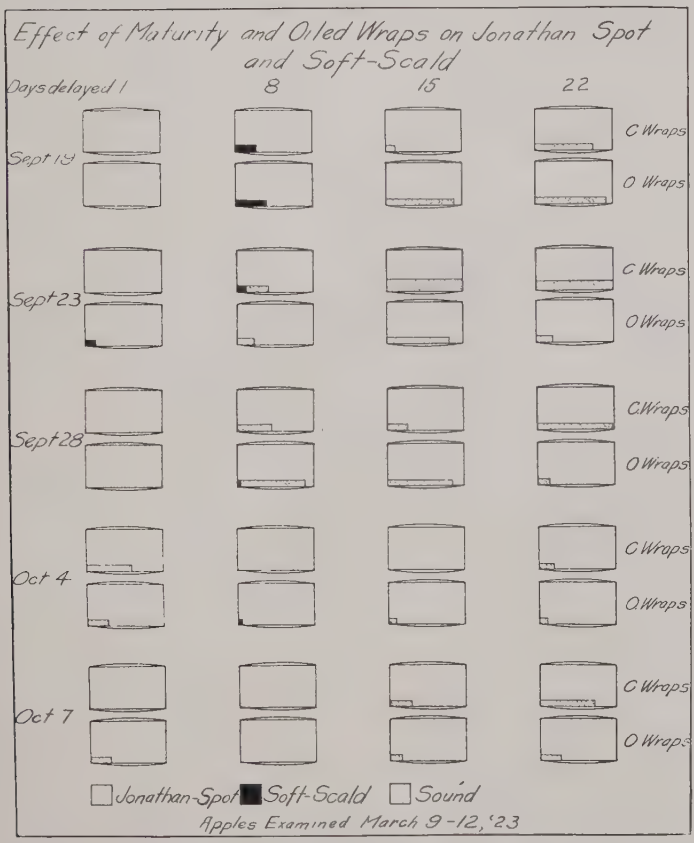

Fig. 6. Diagram showing the amount of Jonathan-spot and soft-scald on Jonathan under aerated conditions in cold storage, in March, 1923. The experiment includes a comparison of the effect of oiled wraps and common wraps. Compare with fig. 5.

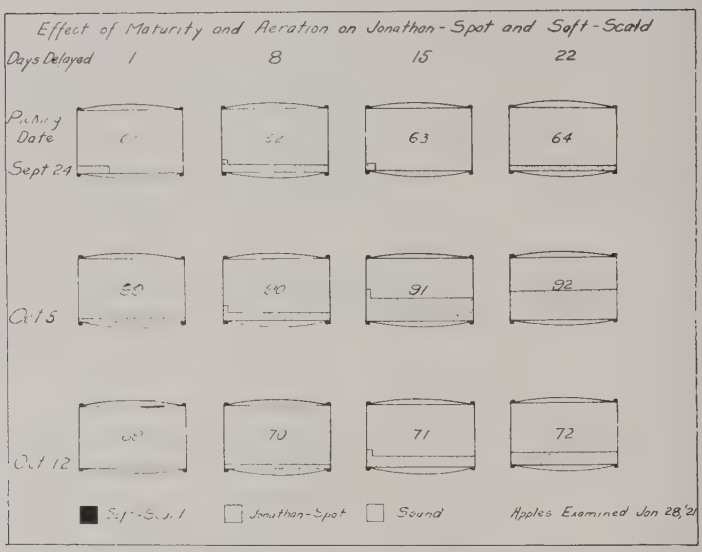

Fig. 7. Diagram showing the amount of Jonathan-spot and soft-scald occurring under aerated conditions in Jan., 1921. Method of indicating amount of Jonathan-spot and soft-scald, and of indicating time of picking and time of storing, is the same as that given in figs. 3 and 4. Note that no soft-scald occurred under areated conditions. Compare these boxes with those picked and stored the same dates in figs. 3 and 4.

Aeration was accomplished by the re-circulation of the air within a storage room by the use of two electric fans having diameters of six inches. One fan was placed on the floor at one side of the room under a false flooring, and faced in opposite direction to another fan placed near the ceiling on the opposite side of the room. A continuous movement of the air was, in this way, maintained, averaging approximately 7/10 of a mile per hour. During the season 1920-21, an occasional freshening of the air within the room was given by opening an outside door, whenever temperatures permitted, so that no great changes within the room took place. Thruout the other seasons, however, no renewal of the air within the room from an outside source was given, except that from opening and closing the corridor doors.

The results with aeration for the season of 1922-23 are shown in figs. 5 and 6 and in table X. Fig. 5 shows the aerated apples; fig. 6, the unaerated apples. With common wrapped apples, aeration decreased Jonathan-spot in some cases, but it did not do so consistently. With fruit in oiled wraps, less

spot developed with aeration than without, but even in this case there is an exception of one box in lot 12.

That Jonathan-spot may not necessarily be controlled by aeration, but may develop even more under this condition was observed in the season 1920-21. The experiment was carried on in the same manner as for the season 1922-23. The apples came from the same orchard, were grown under the same cultural practices and were graded, packed and stored in a similar way. Likewise, a temperature of 32°F. and a humidity of 85 to 90 percent were maintained for each storage season and the aeration was afforded by the use of electric fans.

The figures giving the outcome of this experiment are given in tables IX and XI. The results of the two conditions can be seen by comparing similar lots in figs. 3 and 4 with fig. 7. In nearly all the boxes, Jonathan-spot is more abundant in the boxes which were stored with aeration.

Aeration experiments were again conducted in the season 1921-22 with Jonathan, which had been grown under irrigated conditions in Idaho. The apples were wrapped in common paper, wax and tinfoil wraps. Some boxes unwrapped, served as checks, under both aerated and unaerated conditions. One lot including all the several wrap treatments was placed under aeration, while another lot with duplicate treatments was placed in a room without aeration. A summarization of the results is given in table XII. Not much Jonathan-spot had developed by January 20. In all cases the amount was less than two percent.

Considering the condition of the fruit in March, with the common wraps, the difference was slight; with the unwrapped apples, more Jonathan-spot resulted with aeration; with the oiled wraps and with waxed wraps, less Jonathan-spot oc-

TABLE XI. EFFECT OF AERATION UPON JONATHAN-SPOT, 1920-21.

No. days delayed	Lot no.	Percentage of Jonathan-spot		Lot no.		
		With aeration			Without aeration	
		Condition			Condition	
		Jan. 28	Mar. 28		Jan. 28	Mar. 28
Apples picked Sept. 24th						
1	1	2.8	35.7	13	0.6	10.3
8	2	11.4	53.1	14	0.0	4.8
15	3	0.8	35.2	15	0.7	18.3
22	4	7.5	38.1	16	0.0	8.0
Apples picked Oct. 5						
1	5	4.7	29.2	17	0.0	12.0
8	6	13.3	50.0	18	0.7	42.4
15	7	39.3	67.4	19	13.1	58.7
22	8	47.8	79.1	20	16.0	72.8
Apples picked Oct. 12						
1	9	0.0	4.9	21	0.0	2.9
8	10	5.0	10.8	22	0.6	14.1
15	11	16.5	22.4	23	5.5	44.2
22	12	19.0	31.9	24	7.9	35.3

TABLE XII. PERCENTAGE OF JONATHAN-SPOT AS AFFECTED BY VARIOUS WRAPS AND BY AERATION, 1921-22.

	Aerated			Not aerated		
Wrap	No. apples	Condition Jan. 20	Condition Mar. 10	No. apples	Condition Jan. 20	Condition Mar. 10
Tissue	1031 (7 boxes)	1.16	8.05	1363 (9 boxes)	0.44	8.93
No wrap	796 (5 boxes)	0.25	11.31	779 (5 boxes)	1.16	8.73
Oil	1207 (8 boxes)	0.08	1.95	1196 (8 boxes)	0.25	6.94
Wax	313 (2 boxes)	0.96	14.40	290 (2 boxes)	0.69	21.40
Tinfoil	292 (2 boxes)	1.37	19.20	315 (2 boxes)	0.00	3.81
Average		0.60	8.16	Average	0.51	8.80

cured under aeration; with tinfoil, the amount of Jonathan-spot was less where no aeration was given. An average of all these results gave practically no advantage to aeration.

That there were differences in the susceptibility of the various lots used with western apples was evident. This might have been conditioned by orchard where grown, time of picking and possibly other variable factors suggested in the following data:

No. of boxes	Lot no.	Date of picking	Percentage of Jonathan-spot
3	48	Sept.—	2.09
4	55	" 17	7.03
1	17	" 15	14.70
13	13	" 5 to 15	38.55
28	29	" 21 to 29	12.29

The above statement in regard to time of picking was obtained direct from each of the growers and in each case the lot number refers to the orchard where grown. It can only be taken as suggestive since the amount of Jonathan-spot shown, involves, or is conditioned by, many variable factors of which may be listed wrapping, irrigating, differences in temperatures during harvest dates and different orchards due to variance in altitudes.

EFFECT OF VARIOUS KINDS OF APPLE WRAPS UPON JONATHAN-SPOT DEVELOPMENT

The benefit derived from the use of various wraps may be observed in table XII. Oiled wraps reduced the amount of Jonathan-spot under aerated conditions, but the difference was not so great where no aeration was given. Jonathan-spot developed with all of the other wrap treatments and the results were more or less variable. It is interesting to note that more spot occurred with wax and with tinfoil wraps than with the other wrap treatments under the aeration conditions. While this same order held true for the wax wraps under the un-

aerated condition, it did not stand the same with the tin-foil wraps. Altho oiled wraps showed an advantage in this test, other unknown factors or conditions may have entered into the outcome of these results.

To further investigate oiled wraps, they were used in conjunction with the maturity experiment conducted in 1922-23. Table X and figs. 5 and 6 show these results. Here again only a slight advantage is noticed in the application of a commercial oiled wrap in control of Jonathan-spot. The differences noted either under aerated or unaerated conditions were not consistent, so that no definite statement, other than that there were indications of a slight advantage in the oiled wraps in controlling Jonathan-spot, can be made. The results show that the question of picking and storing at the proper maturity is more important than the employment of oiled wraps, or aeration in the prevention of Jonathan-spot.

It may be well to note that commercial oiled wraps have a distinct advantage over other wraps, because they reduce the amount of shriveling of the apple skin. In addition, no deleterious effect results in the use of these wraps from the standpoint of undesirable tastes or odors.

DISCUSSION OF EXPERIMENTS ON JONATHAN-SPOT

Experiments with Jonathan under controlled temperature conditions showed that the storage temperature has a decided influence on the development of Jonathan-spot. In practically every case the higher temperatures gave more Jonathan-spot. Maintaining the proper temperature is an important factor in the control of Jonathan-spot. This temperature, for the majority of cases, was 32°F.

Experiments involving humidity conditions showed that more Jonathan-spot developed at the higher humidities. However, in cold storage houses a low humidity is not to be recommended, because of the danger of the fruit becoming shriveled. Altho Jonathan stored at a relative humidity of not lower than 80 percent and not higher than 90 percent has given more Jonathan-spot than a relative humidity of from 60 to 70 percent, the higher relative humidity is recommended for all around optimum storage conditions. Humidity experiments have given little promise as a practical method for controlling Jonathan-spot in cold storage.

Observations over eight storage seasons have shown that variations in the size of the fruit do not have much influence on the development of Jonathan-spot.

Varying the soil treatment in the orchard, likewise, gave little promise as a method of eliminating Jonathan-spot. Varia-

tions in the amount of the disease between the seasons are usually more than the variations between the soil treatments for any one year and indicate that other conditions are more important in the development of Jonathan-spot. Probably the maturity of the fruit, and the amount of red color as conditioned by soil treatments varies the amount of Jonathan-spot. Other experiments, measuring accurately the maturity conditions of the fruit, are desirable.

Jonathan-spot appeared to be more abundant one season than another. The effect of meteorological conditions from year to year in Jonathan-spot development has been considered over the period from 1915 to 1922. No very definite correlations between the amount of rainfall, mean temperatures, and the amount of sunlight have been observed. However, the amount of rainfall from year to year has not varied greatly for this period. In general, seasons with the greatest amount of sunshine have shown a slight decrease in the amount of Jonathan-spot; but in 1919 the opposite was true. It appears that no one of the meteorological factors considered is the sole cause governing the amount of Jonathan-spot developing. Perhaps there is a composite factor, based on several meteorological factors, combined with still others, such as nutrition, variety characteristics, physiological activities and storage conditions, which is important in conditioning the amount of Jonathan-spot from season to season.

Common storage experiments compared with cold storage conditions showed that the time of storing is important in each case. Delayed stored cold storage apples developed more Jonathan-spot by January 1 than immediately stored common storage apples under both conditions of early and normally picked fruit. But by April 10 the immediately stored common storage fruit had developed a much higher percentage of the number of Jonathan-spotted apples for both early and normally picked fruit. This emphasizes that Jonathan can be held longer in cold storage than in common storage.

The effect of the maturity of the fruit as a factor on Jonathan-spot development has been given special attention for six years. In general, fruit stored in a late condition of maturity has developed more Jonathan-spot than fruit stored in the early stages of maturity. This has been true for both cold storage and common storage fruit in 1917-18. Thruout the seasons of 1919, 1920 and 1922, inclusive, apples upon which careful orchard records had been secured were stored in cold storage. These records show the maturity of fruit according to dates picked and stored, color of fruit, of seeds and ease of picking, and give a fair estimate of the condition of the fruit when

placed in storage. The results for these periods have been usually the same from year to year, late picking and late storing giving the greatest amount of Jonathan-spot. Where exceptions occur, to this general condition, they usually can be accounted for on the basis of variations in packing, shed temperatures during the period of delayed storage, or to differences in the grading of the fruit resulting in color differences. Doubtless the most significant thing brought out in these experiments with immediate storage, which, in this case, consisted of a delay of 24 hours, is that the amount of Jonathan-spot has been reduced to a minimum. This amount of spot in all cases has been of practically no commercial importance on the dates that the fruit was first inspected. These dates for the different seasons are as follows: 1919-20, February 17; 1920-21, January 28; 1922-23, March 10.

All of these dates are well into or beyond the commercial storage period of the Jonathan variety. In 1922-23, apples picked on October 4, stored immediately and examined on March 10, had as high as eight percent of Jonathan-spot, but in this case the apples were picked beyond the optimum harvest date and were stored over two months beyond their normal storage period before they were examined. The apples with the highest amount of Jonathan-spot at the time of the first inspection, usually continued to have the highest amount of spot at the second inspection. Since Jonathan-spot becomes more severe in the latter part of the storage season, Jonathan should not be held later than the first of January.

There is a tendency for the amount of Jonathan-spot to increase with delayed storage and in proportion to the length of delay. In case immediate storage is impractical in a large orchard, this would emphasize the importance of storing the fruit soon after picking. For example, considerable differences would probably result between fruit which was stored at the end of one week and fruit stored after three weeks delay, altho it was all picked at the same time.

Altho late picking has increased the amount of Jonathan-spot on fruit over early picking, it does not appear to be as important as delayed storage in the development of this disease. The warm harvest season temperatures apparently exert a greater influence on the disease on picked fruit than fruit on the trees. These differences may be due to variance in the ripening processes of the fruit under the two conditions. Since late picking exerts less influence than late storing on Jonathan-spot development, Jonathan should be stored soon after they are picked.

Aeration experiments as accomplished by the recirculation of the air within the storage room have had but little if any effect upon the control of Jonathan-spot. An air movement ap-

proximating an average of seven-tenths mile per hour thruout the period of storage in 1920-21, with an occasional renewal of the air from an outside source, has given more Jonathan-spot, rather than less, as compared to a similar lot of Jonathan in another room where no movement or exchange of air was given. Further experiments in 1921-22 and 1922-23 corroborate these results and show no consistent advantage in employing the aeration method for Jonathan-spot control.

Experiments with oiled wraps for two seasons indicate that Jonathan-spot cannot be controlled by this method. Comparisons of wax and tinfoil wraps with common and oiled wraps have shown no outstanding results regarding the occurrence of Jonathan-spot. The results are such that they probably are more intricately affected by other experimental and physiological factors than either the aeration, or oiled wrap conditions. An advantage of oiled wraps over common paper wraps is that the former do reduce the amount of shriveling of the skin of the apple. No deleterious effect has resulted in the use of the oiled wrap.

SOFT-SCALD

Soft-scald is the superficial browning of the skin of the apple, which extends to a certain extent into the flesh and appears in areas of various shapes and outline on the surface. The disease in its earliest stages involves only the skin of the apple, but, with later development, may extend well into the flesh, causing it to become brown in color and soft in texture. After removal from cold storage conditions, the affected portion becomes sunken and slightly corky. The discoloration of the skin which is at first a light shade of brown, later, may become a much deeper color after the conditions of storage have been changed. The size of the areas becoming affected may vary from one-sixteenth inch in diameter to the extent of covering nearly the whole surface of the apple. Under certain conditions, secondary rots usually invade the affected portions

The disease is peculiar in that it is confined to certain areas of the apple. The portions of the fruit adjacent to the stem and calyx ends seem to be practically immune to the disease, while the remainder of the surface of the apple may be affected in various degrees. In severe cases, soft-scald extends entirely around the apple in a circular band. This band usually varies widely in width. After the trouble has reached a certain stage of development, the areas affected remain the same and do not become larger. This suggests that the maturity of the apple may influence the development of the disease.

Ramsey, McKay, Markell and Bird (5) have reported soft-scald as occurring on Jonathan, Blue Pearmain and Wealthy.

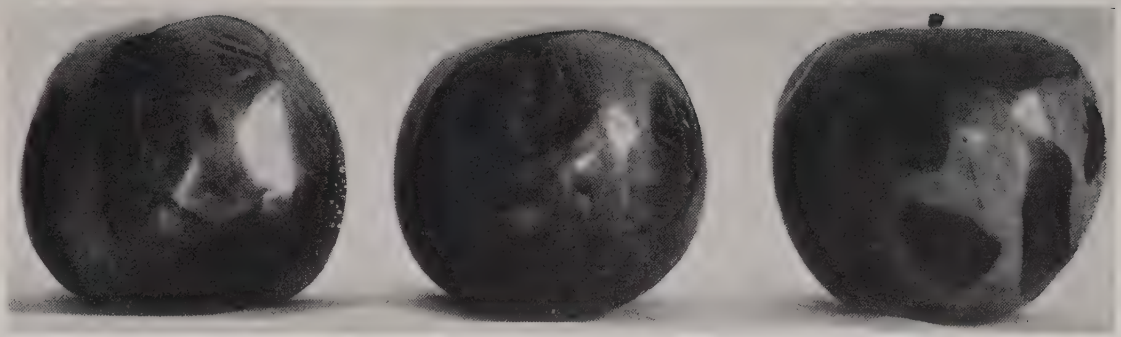

Fig. 8. Soft-scald on Jonathan in severe stages, showing various outlines in which the disease manifests itself.

Fig. 9. Development of soft-scald in the flesh of the apple. Section at the right shows how the diseases may encompass nearly the entire circumference of the apple, leaving the center entirely free.

Fig. 10. Soft-scald on Jonathan, Aug. 27. These apples were removed from cold storage in April and placed in ordinary basement storage. On Aug. 27, soft-scald areas had not become larger or had not spread more deeply into the flesh of the apple.

Whitehouse (7) has described this disease under the name of brown dry rot, appearing on Jonathan and Northwestern Greening. Brooks, Cooley and Fisher (3) have stated that soft-scald is particularly common on the Jonathan and Rome Beauty varieties. In Iowa, soft-scald commonly occurs upon Jonathan, Wealthy and Northwestern Greening. At Ames, in connection with the apple breeding work, it has been found practically every year on certain seedling apples. Soft-scald has been more serious in some years than in others. Frequently, Iowa fruit growers have reported the occurrence of this disease and it is sometimes a serious consideration in the storage of Jonathan.

EXPERIMENTS DEALING WITH THE NATURE OF SOFT-SCALD.

In 1919-20, the writers carried out some careful experiments with soft-scald to determine whether or not some organism was associated with this disease. Of repeated attempts made, negative results were always obtained. No organism was found.

In January of the same season, the effect of higher temperatures and higher humidities upon soft-scald was tried out. Jonathan apples affected with the disease in various stages of severity were selected. The affected areas were outlined with a sharply pointed indelible pencil. One lot of apples was placed in a moist chamber at 32°F. A similar lot was placed at 70°F. After a period of 55 days the soft-scald spots had not increased in size. At either temperature, no increase in the area of the marked soft-scalded spots could be observed. Parallel with the above experiment, some affected Jonathan apples were held in

ordinary basement storage from the middle of April until August, when it was noticed that altho soft-scalded parts of the apples had dried out and had become corky in texture, they had not spread in area or depth. The unaffected portions of the apples were apparently sound, where no fungus rots had made their appearance. Fig. 10 shows the condition of these apples on August 27, after being in basement storage over four months.

During the following season of 1920-21, similar experiments were carried on. Thirty-two Jonathan apples affected with soft-scald were marked with indelible pencil. Twenty-one of the specimens were placed at 32°F. under a relative humidity of 85 to 90 percent, while the other 11 apples were held at living room conditions. No increase in the size or number of affected areas could be noticed in either case.

In still another experiment, 60 soft-scalded Jonathan apples were used. The affected portions were marked as before. Only apples free from rot fungi were selected. Twenty-five specimens were wrapped in dry paper wraps and 25 in water-soaked paper wraps. Each lot was placed in separate boxes at 32°F. Ten specimens which were left unwrapped were placed in the same storage room on top of the boxes.

After 30 days all specimens were examined and in no case had the soft-scalded areas spread or increased in size. The apples were kept for further examination and the wet wrappers were resoaked with water. As late as June 14, which was 105 days after the experiment was started, it was noticed that no spreading or increasing of the soft-scalded areas had taken place on any of the apples under wrapped and unwrapped conditions.

All of the above experiments were performed during the latter part of the storage season, after January first. The results of these experiments lead to the conclusion that soft-scald is more likely to occur early during the storage period, some time previous to the time that the above tests were carried out. Dampness of apple wraps or high humidities have had no effect upon its further development. Temperature and humidity changes apparently have not been responsible for its subsequent development. Since soft-scald has occurred upon all susceptible apples within certain lots only, it seems that there are peculiar storage conditions under which it becomes observable. It appears that soft-scald may be largely influenced by the maturity of the apples when placed into cold storage.

THE RELATION OF MATURITY TO SOFT-SCALD.

The amount of soft-scald was observed on Jonathan apples in a maturity and delayed storage test in 1919-20. Table XIII

shows how the experiment came out with reference to soft-scald.

In the first place it is interesting to note that unlike Jonathan-spot, soft-scald had not developed much after a certain period in storage. Most of the disease had developed by February 17.

In the second place, soft-scald had not appeared until February 17, on the apples harvested the last picking date, and for those stored after 15 and 22 days of delay, but picked earlier, on October 7. From this it is inferred that soft-scald is conditioned by maturity and is more likely to be present on apples having the least maturity. A more critical study of the data in this table suggests that the apples delayed from 8 to 15 days are more subject to soft-scald than those given less or more than this period before storing.

In 1920-21 similar evidences were obtained to show that the degree of maturity affects the amount of soft-scald. The results of the experiment are shown in table XIV. The general plan of the experiment was the same as for the maturity tests on Jonathan-spot. Figs. 3 and 4 graphically present the data for the amount of bad soft-scald.

These results show that delayed storage of two to three weeks was advantageous in decreasing soft-scald. Delaying the apples as much as three weeks gave the best results and on three dates has completely prevented bad soft-scald.

TABLE XIII. RELATION OF MATURITY TO SOFT-SCALD ON JONATHAN, 1919-20

Lot no.	Date of picking	No. of days delayed	Percentage of total soft-scald	
			Condition February 17, 1920	Condition April 1, 1920*
1	Sept. 23	1	0.0	2.1
2	"	8	33.1	6.7
3	"	15	1.5	0.0
4	"	22	0.0	0.0
5	Sept. 27	1	10.0	1.0
6	"	8	9.5	1.1
7	"	15	17.8	0.6
8	"	22	0.5	0.0
9	Oct. 2	1	4.6	0.5
10	"	8	11.1	0.5
11	"	15	0.9	0.9
12	"	22	0.4	0.0
13	Oct. 7	1	4.4	3.6
14	"	8	3.5	1.5
15	"	15	0.0	0.0
15	"	22	0.0	0.0
17	Oct. 12	1	0.0	0.0
18	"	8	0.0	1.4
19	"	15	0.0	0.7
20	"	22	0.0	0.6

*Soft-scalded specimens which were affected severely enough to be of no commercial value were eliminated at the time of the first inspection.

TABLE XIV. EFFECT OF MATURITY ON SOFT-SCALD ON JONATHAN, 1920-21.

Box no.	No. apples	No. days delayed	Percentage of soft-scald					
			Condition, Jan. 28			Condition, March 28		
			Slight	Medium	Bad	Slight	Medium	Bad
Apples picked Sept. 24.								
25	155	1	1.9	0.0	1.2	1.9	0.6	1.2
26	144	8	9.0	3.4	10.4	11.8	5.5	12.5
27	126	15	0.0	0.0	2.3	0.0	0.0	2.3
28	175	22	0.5	0.5	0.0	1.1	0.0	0.0
Apples picked Sept. 27.								
29	138	1	6.5	6.5	11.5	7.9	7.9	14.5
30	125	8	5.6	0.8	4.8	8.8	4.0	5.6
31	138	15	2.7	0.0	1.4	4.3	0.7	1.4
32	163	22	1.8	0.0	0.0	4.9	0.0	0.0
Apples picked Oct. 1.								
33	138	1	15.9	5.0	4.3	26.5	7.2	7.2
34	162	8	8.6	4.3	18.5	22.2	7.4	22.2
35	137	15	1.4	2.9	5.1	4.3	6.5	6.5
36	163	22	1.2	0.0	0.0	4.9	1.2	0.0
Apples picked Oct. 5.								
37	125	1	7.2	3.2	7.2	8.0	6.4	10.4
38	139	8	7.2	2.8	8.6	11.5	6.4	10.0
39	138	15	5.0	1.4	3.6	8.7	3.6	5.0
40	125	22	0.0	0.0	2.4	0.0	0.0	2.4
Apples picked Oct. 9.								
41	138	1	4.3	1.4	5.0	7.9	5.0	10.1
42	125	8	0.0	4.0	10.4	1.6	8.0	10.4
43	163	15	7.3	3.0	6.1	14.7	8.5	9.2
44	186	22	6.9	0.5	0.5	16.7	6.4	2.6
Apples picked Oct. 12.								
45	134	1	5.2	4.4	5.9	9.7	7.4	7.4
46	163	8	1.2	5.5	17.8	6.1	8.5	20.2
47	163	15	0.0	0.0	0.6	3.0	1.8	0.6
48	188	22	2.1	1.0	0.5	4.7	2.6	0.5

Delaying at the orchard one week has given the greatest amount of soft-scald for every lot except one, in which case immediate storage has been the least beneficial. Delaying two weeks or three weeks was best from the standpoint of soft-scald control.

Soft-scald and Jonathan-spot are not usually associated together and do not often occur to any great extent within the same box of apples or upon the same apple. Figs. 3, 4, 5, 6 and 7 indicate this to be the case in nearly every comparison made. It has been repeatedly noticed in Jonathan apples that when an apple has been badly affected with Jonathan-spot it very seldom has any soft-scald. The same has been noticed for badly soft-scalded apples.

That soft-scald will vary in severity according to season was noticed when the results of the season 1922-23 were obtained. Figs. 5 and 6 show that the Jonathan apples used did not become severely affected with soft-scald. But the results show that the earliest picked apples were the most susceptible. When it comes to delayed storage, 15 days delay, or more, entirely prevented its occurrence. Attention is called again to the fact that there was more soft-scald on apples delayed 8 days than on those stored immediately.

The results for the season 1922-23 correspond with those of

1920-21. Apples which were slightly immature soft-scalded worse than mature ones. Delayed storage of 15 days or more tended to reduce the amount of soft-scald. The Jonathan used in 1920-21 soft-scalded worse than those used in 1922-23, however.

EFFECT OF AERATION ON SOFT-SCALD

Aeration as a means for controlling soft-scald was studied in 1920-21 and 1922-23. For the first season, 12 boxes of Jonathan were placed in cold storage under aerated conditions. Twelve similarly treated boxes of the same maturity were placed under the same conditions except for aeration. The experiment included three different picking dates and the apples were stored at four different times for each lot picked. The experiments were carried on in the same way as those for Jonathan-spot. The results of this test are shown in figs. 3, 4 and 7. No soft-scald was present in the aerated boxes on January 31, but all of the unaerated boxes except one had soft-scald present at this time. The aeration in this case consisted of recirculating the air with small electric fans and an occasional renewal of fresh air when temperatures permitted the opening of an outside door of the cold storage room. In no case was this door open for more than an hour at one time, so that no prolonged change in temperature and humidity took place.

The above results indicate that aeration by recirculating the air within the cold storage room and an occasional freshening with outside air, was beneficial in controlling soft-scald. These results are in harmony with the work of Brooks, Cooley and Fisher (3) in which they reported the advantage of ventilated barrels, over tight barrels in decreasing the amount of this disease.

To gain further evidence on the relation of aeration to this disease, a test very similar to that reported above was carried out in 1922-23. These results are shown in figs. 5 and 6. In this case aeration did not appear to be satisfactory as a control measure for soft-scald. It may be possible to explain this disagreement with the previous experiment, because no fresh air was introduced in the case of the latter experiment. More experiments on this point are desirable.

RESULTS OBTAINED BY USE OF WRAP TREATMENTS ON SOFT-SCALD.

Observations on the control of soft-scald by the use of oiled wraps were made upon Idaho Jonathan apples during 1921-22, but so small an amount of the disease was present that no statement of the results is considered worth while. The test suggests that wide variations may be expected from year to year

in the amount of soft-scald and western grown Jonathan may be less susceptible to the disease than eastern grown apples.

During the season 1922-23, oiled wraps as a soft-scald preventive measure were compared with ordinary paper wraps on apples of different maturities. These results are depicted in figs. 5 and 6. It will be noticed that oiled wraps have not consistently prevented soft-scald. These figures show in some cases that more soft-scald has occurred with oiled wraps than without.

DISCUSSION OF EXPERIMENTS ON SOFT-SCALD.

Experiments showed that no organism is associated with soft-scald. Removing soft-scalded apples from cold storage, as late as January first, checked the disease entirely. Soft-scalded specimens held in cellar storage from April until late in August did not show any increase in soft-scald. Increasing the humidity of storage did not increase the amount of the disease. Soft-scald is more likely to occur quite early in the storage season on either unwrapped or wrapped fruit.

Maturity experiments have shown that soft-scald is largely conditioned by the maturity of Jonathan when placed in cold storage. Tho time of picking and time of storing are both important, time of storing is the more important. Apples given a delay of 8 to 15 days before storing soft-scalded worse than those stored immediately or those given a delay of 22 days Delaying at the orchard seven days usually has given a greater amount of soft-scald than immediate storage, or delayed storage of 14 to 21 days. A delay of two or three weeks has given the best results in soft-scald control. However, long delay in storing Jonathan makes the risk of Jonathan-spot much greater than immediate storage or a shorter delay. With Jonathan, the maturity of the fruit influences two storage diseases; undermaturity increases soft-scald and over-maturity increases Jonathan-spot. With Jonathan, more experiments measuring accurately exact maturity conditions are desirable.

Soft-scald and Jonathan-spot did not occur abundantly under the same conditions of maturity, simultaneously. Apples which soft-scalded seldom were affected severely with Jonathan-spot, or vice versa. Western grown Jonathan apples, practically free from soft-scald, were very subject to internal breakdown. Iowa grown Jonathan, practically free from internal breakdown, were very subject to soft-scald. Comparisons of the amount of soft-scald from year to year showed that it may be more prevalent one year than another.

In 1920-21, aerating by recirculating the air of the cold storage room, with occasional ventilations of outside air, complete-

ly controlled soft-scald on Jonathan. This was true one season on both early and late picked fruit and for both immediate and delayed stored fruit. In another season when aeration was carried out in the same way, but with no ventilation of outside air, aerating did not prove satisfactory. Oiled wraps have not satisfactorily controlled this storage disease on Jonathan during two different storage seasons.

INTERNAL BREAKDOWN.

With Iowa grown Jonathan, internal breakdown has never been a factor in the cold storage experiments reported.

During one cold storage season, when western grown Jonathan were used exclusively, internal breakdown was of more consequence than either Jonathan-spot or soft-scald. In the lot of apples used, breakdown was already present when the apples were received, it being necessary to discard approximately five percent of the fruit before starting the experiment. Later, when further observations were made, 6.2 percent more of the apples were found affected with internal breakdown. These apples coming from different orchards were picked at about the average date for the region where grown. They were shipped under ventilation, without refrigeration, and were en-route seven days. They were given the amount of irrigation customary for the section where grown.

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SUMMARY—PART II.

1. Soil treatment experiments did not show wide differences in amount of apple-scald developing from year to year. Slight decrease in scald usually noticeable with the bluegrass sod treatment, was attributed to earlier maturity of the fruit.

2. Maturity experiments showed that apple-scald is largely conditioned by the maturity of the fruit when it is stored.

3. Grimes picked in an immature condition scalded badly. Those picked in a more mature condition were immune to scald.

4. Delayed storage usually decreased the amount of scald on mature fruit. This decrease was not always in proportion to the amount of delay.

5. Aeration did not control apple-scald. Aeration with ventilation likewise proved unreliable on fruit stored in a somewhat immature condition. Only apples which were in an immature condition when stored were benefited by aeration. The advantage of aeration was most apparent on unwrapped apples.

6. Oiled wraps were far more effective as a scald preventive than aeration and apples in an immature condition responded best to this treatment. With Wenatchee grown Grimes, oiled wraps controlled scald in all cases.

7. Apples scalded worse in wax wraps and in tinfoil wraps than in common paper wraps, or unwrapped apples.

8. Artificial scald, produced by ethyl acetate and acetaldehyde, was delayed or entirely prevented by wrapping apples in oiled wraps. Aerating apples, exposed to ethyl acetate, greatly reduced the amount of scald.

9. Experiments with Grimes, considering maturity when stored, showed that the chances for the occurrence of breakdown increased with late picking as well as with delayed storing. Late picking with immediate storage was comparable to early picking with late storage in the amount of breakdown.

10. Scald prevention methods, wrapping in oiled wraps and aerating the storage room were not effective in reducing internal breakdown.

11. Differences in the rate of cooling between unwrapped, oiled paper wrapped, and common paper wrapped apples were slight and probably of no commercial significance. The rate of cooling of common paper wrapped boxed apples was approximately two-thirds that of tinfoil wrapped apples.

12. Rate of increase in temperature of unwrapped apples was approximately twice that of paper wrapped, and 1.6 times that of tinfoil wrapped. Differences noted in the rate of cooling between aerated and unaerated wrapped apples were only slight.

II. APPLE-SCALD AND INTERNAL BREAKDOWN

APPLE-SCALD

Apple scald is the superficial brown discoloration of the skin of the apple that frequently occurs upon fruit in storage, or upon fruit when removed from storage. It usually involves only the surface layers of the cells of the apple, but in the latter stages the disease may extend beyond the skin layer into the flesh cells of the fruit. Scald manifests itself upon the fruit in various ways. It often involves a large portion of the surface of the skin. It may occur in small spots on only a small portion of the surface of the fruit, or over the entire surface, giving the apple a tinted brown appearance.

A trace of scald not only detracts from the appearance of the fruit, but it is likely to develop into severe scald in a few days after the apples are placed on the market. When scald appears, it is hazardous to hold the fruit longer and it is usually sold as soon as possible, regardless of market prices.

Some varieties which are especially apt to scald in cold storage are Arkansas, Grimes, Rome, Sheriff, Yellow Newtown, York Imperial and Winesap. Some varities which seem to be practically immune to apple scald are Willow Twig, Northern Spy, Jonathan, Missouri Pippin and Ralls.

EFFECT OF SOIL TREATMENTS ON SCALD DEVELOPMENT

To note the effect of various methods of soil treatment on scald development, records have been made of the amount of scald developing on Grimes apples grown under each of the four types of soil culture practiced at the State Experimental Orchard, Council Bluffs, Iowa.

The following table shows the results of four years observations on the variety, Grimes. These apples were examined during March in 1915-16 and during February in the other seasons.

TABLE I. EFFECT OF VARIOUS SOIL TREATMENTS ON SCALD DEVELOPMENT ON GRIMES.

Soil treatment	Percentage of bad scald.					
	32°F.				40°F.	
	1914-15	1915-16	1916-17	1917-18	1916-17	1917-18
Clover sod	26.5	....	2.5	42.0	36.3	51.1
Cover crop	24.8	....	2.6	34.5	37.7	85.7
Clean tillage	20.6	....	2.3	43.5	30.6	....
Blue grass sod	20.2	....	0.2	38.3	22.8	....
	Percentage of total scald.					
	32°F.				40°F.	
Clover crop	69.2	10.7	6.9	96.0	86.1	99.8
Cover crop	71.6	28.8	9.1	97.3	82.2	100.0
Clean tillage	68.5	30.9	8.4	95.0	82.5	....
Blue grass sod	93.7	18.9	2.4	88.6	80.0	....

The different types of cultivation under which these apples were grown had very little effect on the scalding of apples in storage. Apples from the bluegrass sod scalded the least as a rule, which was probably the result of being more mature at picking time. With the Grimes Golden, which is one of the first varieties picked during the harvest, it was necessary to pick, while still a little immature, in order to prevent premature dropping. Observations made in the orchard have shown that the apples from the bluegrass sod were the first to mature in the fall. The records of the packing house, where the fruit was sorted and graded for color, show 20 to 30 percent more color on those apples grown on the bluegrass sod, as compared with others. This again emphasizes that one of the determining factors in the development of apple-scald is the maturity of the apple at the time of storing.

EFFECT OF DEGREE OF MATURITY AND DELAYED STORAGE UPON SCALD DEVELOPMENT.

Brooks, Cooley and Fisher (4) have pointed out that it is generally accepted that immature apples scald more than mature apples. This condition is corroborated in the investigations of Powell and Fulton (9), Ramsey, et al. (11), and Whitehouse (12).

Table II shows the amount of scald which developed in the different boxes under the treatments for the season 1919-20. In this case more scald developed on the late picked fruit than on the early. Generally there was more scald in the boxes which were given delayed storage than in those which were

TABLE II. SCALD ON GRIMES—SEASON 1919-20. TREATMENT, VARYING PICKING DATE AND DELAYING STORAGE PERIOD.

Percentage of scald.

Lot no.	No. of apples	No. days delayed	Condition					
			Feb. 11			March 30		
			Slight	Medium	Bad	Slight	Medium	Bad
Apples picked Sept. 23.								
1	163	1	0.0	0.0	0.0	19.8	11.1	2.3
2	150	8	0.0	0.0	0.0	5.9	7.9	1.2
3	175	15	3.7	0.0	0.0	21.6	3.7	0.6
4	175	22	13.1	1.6	0.0	14.3	12.5	6.8
Apples picked Sept. 27.								
5	187	1	0.0	0.0	0.0	0.0	0.0	0.0
6	185	8	1.6	0.0	0.0	0.0	0.0	0.0
7	182	15	15.9	13.7	1.1	31.4	19.6	10.6
8	186	22	8.0	2.1	0.0	19.8	16.4	16.4
Apples picked Oct. 2.								
9	164	1	0.0	0.0	0.0	0.0	0.0	0.0
10	176	8	0.0	0.0	0.0	2.7	3.4	1.3
11	181	15	2.7	4.4	3.3	14.4	14.4	11.3
12	203	22	4.9	0.0	0.0	16.0	9.5	4.5
Apples picked Oct. 7.								
13	163	1	0.0	0.0	0.0	0.0	0.0	0.0
14	153	8	3.2	1.3	0.0	6.7	3.0	1.5
15	165	15	17.5	6.6	5.4	9.9	16.5	45.0
16	165	22	15.1	8.4	6.6	17.7	14.6	47.2

TABLE III. SCALD ON GRIMES—SEASON 1920-21. TREATMENT, VARYING PICKING DATE AND DELAYING STORAGE PERIOD.

Percentage of Scald.

Lot no.	No. of apples	No. days delayed	Condition					
			Jan. 25			March 24		
			Slight	Medium	Bad	Slight	Medium	Bad
Apples picked Sept. 14.								
1	180	1	22.2	15.0	26.1	16.1	21.1	49.4
2	198	8	13.6	8.0	7.5	23.2	11.6	22.2
3	197	15	0.0	0.0	0.0	0.0	0.0	0.0
4	150	22	2.6	0.0	0.0	7.3	6.0	4.0
Apples picked Sept. 20.								
5	163	1	30.6	8.5	3.0	17.1	19.6	46.6
6	175	8	9.1	0.0	0.0	17.7	12.5	13.7
7	148	15	29.0	10.8	7.4	18.2	14.9	52.7
8	165	22	7.2	1.8	0.0	10.9	2.4	8.5
Apples picked Sept. 24.								
9	142	1	7.0	0.0	0.0	26.1	6.3	22.5
10	175	8	6.8	0.0	0.0	18.3	13.1	12.1
11	150	15	17.3	4.6	3.3	13.3	17.3	40.7
12	174	22	6.9	3.4	0.0	21.2	8.6	14.9
Apples picked Sept. 28.								
13	139	1	1.4	0.0	0.0	8.6	1.4	3.6
14	150	8	0.6	0.0	0.0	8.0	2.6	0.0
15	175	15	0.0	0.0	0.0	14.3	9.1	5.7
16	125	22	0.0	0.0	0.0	12.0	1.6	0.0
Apples picked Oct. 2.								
17	163	1	0.0	0.0	0.0	0.0	0.0	0.0
18	176	8	0.0	0.0	0.0	1.1	0.6	3.3
19	150	15	0.0	0.0	0.0	9.3	3.3	3.3
20	143	22	0.0	0.0	0.0	23.8	3.5	2.8
Apples picked Oct. 5.								
21	188	1	0.0	0.0	0.0	0.0	0.0	0.0
22	125	8	0.0	0.0	0.0	0.0	0.0	0.0
23	150	15	0.0	0.0	0.0	2.6	0.0	0.0
24	175	22	0.0	0.0	0.0	1.7	0.0	0.0

stored immediately. This is in agreement with the results obtained by other investigators (7). Discrepancies may be explained, in part, on the basis that the apples used in this particular season were of orchard run grade, which may have included many small and immature specimens.

The data showing the amount of scald for the following season are given in table III. The first date, September 14, was considered somewhat early for this variety and on the late date, October 5, the apples were quite mature, a yellow color having made its appearance. Figs. 11 and 12 show the amount of scald graphically. In these figures the scald shown is the percentage of bad scald present when first inspected late in January. It will be noticed that all of the bad scald occurred in the first three pickings and the greatest amount in the box picked first and stored first.

These results show that there is not much gained in delaying the storage period unless it becomes necessary to pick the apples when they are quite immature. If apples are picked when mature, there is no advantage in delayed storage from the standpoint of scald control, and they can be stored at once. The data for the inspection in March further emphasizes the im-

portance of not holding this variety too long in storage and indicates that the immature fruit scalds worse than the mature.

Further data emphasizing the importance of maturity in its relation to the scalding of apples was obtained in the season 1922-23. The results for the season are set forth in tables IV and V for the varieties Grimes and Arkansas, respectively. From table IV it will be seen that the Grimes picked slightly immature were subject to scald and the more immature they were the more likely they were to scald.

If it becomes necessary to pick Grimes apples prematurely, it is advantageous from the standpoint of scald prevention to wait a week or two before placing them in cold storage. When Grimes apples are mature, the danger of scalding is at a minimum and they should be stored immediately to avoid the risk of internal breakdown.

Arkansas apples picked when immature are very subject to scald. Neither aerating nor wrapping with oiled paper controlled the development of scald when picked immaturely. Those boxes picked latest had the least amount of scald. The lot delayed 10 days and then stored without aeration had 37

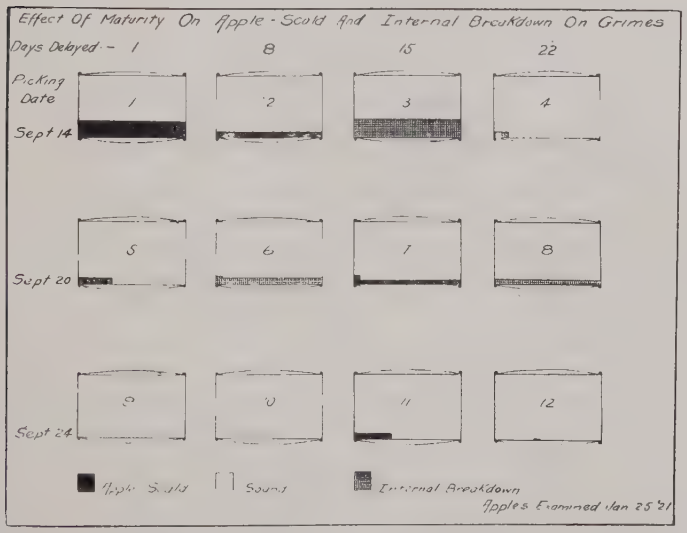

Fig. 11. Diagram showing the amount of apple-scald and internal breakdown on Grimes in Jan., 1921. Black portions of the boxes indicate the percentage of apples affected with apple-scald; shaded portions, the percentage of apples affected with internal breakdown. All of the percentages are based on the number of apples in the boxes at the beginning of the experiment.

percent less scald than the check lot stored at once with aeration.

EFFECT OF AERATION UPON SCALD DEVELOPMENT.

The value of aeration as a scald preventative has been pointed out by Brooks, Cooley and Fisher (3, 4, 5, 6, 7). These investigators emphasized the importance of ventilation and aeration and have shown that aeration is especially important for apples which are being delayed before placing them in storage.

In the experiments described in this report, the apples which were packed in standard apple boxes and placed in small stacks in an open packing shed, in the full sweep of the wind, were probably well aerated during the delayed storage period.

Subsequent aeration during the delayed storage period was not attempted, for the reason that it was not considered practical to leave fruit longer than a day or two in open containers, in an open shed. Apples left in open crates usually become thoroly coated with dust, which is very undesirable when handling fruit in a commercial way.

Aeration in the storage room was accomplished by means of

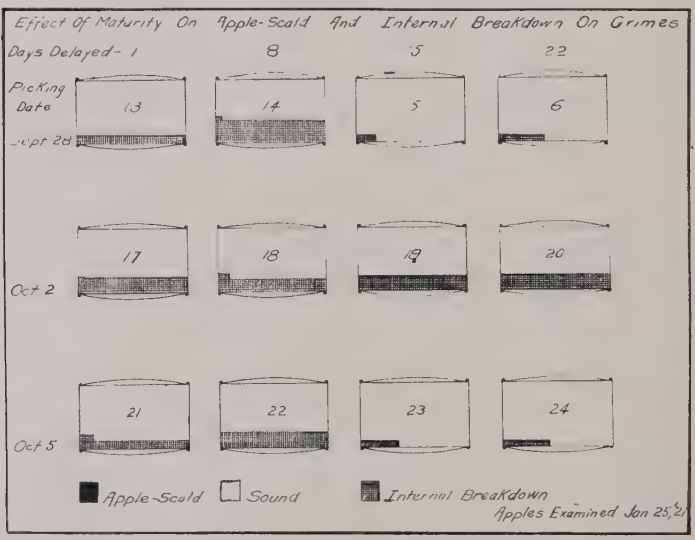

Fig. 12. Diagram showing the amount of internal breakdown on Grimes in Jan., 1921. No bad scald occurred in any of the boxes shown. Shaded portions show the percentage of apples affected with internal breakdown. All of the percentages are based on number of apples in the boxes at beginning of the experiment.

TABLE IV. RELATION OF MATURITY AND EFFECT OF AERATION AND OILED WRAPS UPON SCALD DEVELOPMENT—GRIMES SEASON 1922-23.

Lot no.	Date of picking	No. days delayed	No. of apples	Date inspected	Percentage of scald in boxes			
					Without aeration		With aeration	
					Common wraps	Oiled wraps	Common Wraps	Oiled wraps
1	Sept. 12	1	388	Mar. 26	46.0	1.6	...	...
2	"	1	351	"	26.0	6.7	...	...
3	Sept. 16	1	576	Mar. 8	20.2	6.0	0.0	0.0
4	"	8	739	"	18.3	0.0	2.1	0.0
5	"	15	752	"	3.7	0.0	0.5	0.0
6	"	22	738	"	2.0	0.0	2.1	0.0
7	Sept. 20	1	501	Mar. 8	0.0	0.0	0.0	...
8	"	8	493	"	0.0	0.0	0.0	...
9	"	15	539	"	0.0	0.0	0.0	...
10	"	22	551	"	3.7	0.0	0.5	...
11	Sept. 25	1	588	Mar. 8	0.0	0.0	0.0	0.0
12	"	8	688	"	0.0	0.0	0.0	0.0
13	"	15	688	"	0.0	0.0	0.0	0.0
14	"	22	739	"	0.0	0.0	1.6	0.0
15	Sept. 30	1	426	Mar. 8	5.6	0.0	0.0	...
16	"	8	439	"	0.0	0.0	0.0	...
17	"	15	476	"	0.0	0.0	0.0	...
18	"	22	489	"	0.6	0.0	0.0	...

two small electric fans, placed in a small room having a false floor. One fan was placed under the false floor, facing the other fan which was placed near the ceiling on the opposite side of the room.

September 30, 1919, eight boxes of Grimes were picked when the fruit was mature and then stored immediately. Four boxes were aerated and four served as checks. By February 12, no scald had occurred on any of the apples. A second examination on March 31 gave only slight differences in the amount of scald, some scald having occurred in the aerated boxes. The results seem to be in accordance with the maturity experiments,

TABLE V. RELATION OF MATURITY TO APPLE-SCALD CONDITION, MARCH 13—ARKANSAS

Lot no.	Date of picking	Treatment	Percentage of scald in boxes	
			Without aeration	With aeration
1	Sept. 16	Common paper	100	100
2	"	Oiled paper	97	100
3	"	Unwrapped	100	100
4	Oct. 2	Common paper, delayed storage 10 days	57	...
5	"	Common paper	...	94
6	"	Oiled paper	87	...
7	"	Unwrapped, smeared with oil	14	6
8	"	Unwrapped	99	100
9	Oct. 10	Common paper	63	5
10	"	Oiled paper	50	57
11	"	Unwrapped	68	75

TABLE VI. SCALD ON GRIMES—SEASON 1920-21. TREATMENT, VARYING PICKING DATE, DELAYING STORAGE PERIOD AND AERATION.

Percentage of scald.

Lot no.	No. of apples	No. days delayed	Condition					
			January 25			March 24		
			Slight	Medium	Bad	Slight	Medium	Bad
Apples picked Sept. 20.								
57	163	1	31.3	17.8	23.3	18.4	12.8	66.3
58	138	8	14.5	1.4	0.0	19.5	6.5	17.4
59	156	15	16.0	1.9	1.2	32.6	13.4	23.1
60	150	22	2.6	0.0	0.0	30.0	4.6	2.6
Apples picked Sept. 28.								
85	175	1	4.5	2.2	1.1	24.5	10.8	16.5
86	172	8	8.7	1.7	0.0	26.7	14.5	20.9
87	188	15	0.5	0.0	0.0	16.5	12.2	12.2
88	150	22	13.3	0.0	0.0	20.6	4.6	4.6
Apples picked Oct. 5.								
65	125	1	0.0	0.0	0.0	0.0	0.0	0.0
66	150	8	0.0	0.0	0.0	0.0	0.0	0.0
67	150	15	0.0	0.0	0.0	0.0	0.0	0.0
68	125	22	0.0	0.0	0.0	4.8	0.0	0.0

which showed little or no scald on the more mature apples. There was no apparent advantage in aeration in this test.

Aeration as a scald preventative was further tested in 1920-21. Four boxes of Grimes were picked on three different dates. Each series of four boxes was duplicated in the maturity experiment for the seoson, therefore, the results obtained under aeration may be checked with those under the maturity test. Table VI gives the results of the aeration experiment and the checks may be seen by noting the results for the apples of comparable lots in table III. Except for the movement of the air within the storage room and an occasional renewal of air when the outside temperature permitted the opening of a door, the apples were under the same conditions thruout.

There were no marked differences between the aerated apples and the apples not aerated. It is significant that the most scald occurred in the earliest picked series. Considering the condition of this series on January 25, the apples of the first box stored under aeration had about eight times as much bad scald as the corresponding box not aerated, while the third box stored under aeration had approximately 1/7 as much scald as the corresponding box not aerated.

The differences as late as March 24 for the first two series picked September 20 and 28, respectively, were generally in favor of the apples without aeration. The results for the third series were about the same, no bad scald having occurred in either case.

The experiments in 1921-22 on scald prevention by means of aeration included observations with the varieties Grimes and Rome Beauty. The Grimes apples in some cases were wrapped in various kinds of wraps, including wax, oil, tissue and tinfoil. Some Grimes were left unwrapped as a control. The Rome

Beauty were given unwrapped and wrapped treatments, others were wrapped in common tissue or commercial oiled wraps. With the Grimes, the aeration was continuous. An experiment comparing immediate and delayed aeration was carried out with the Rome Beauty.

The outcome of the test with Grimes may be seen by a comparison of tables VII and VIII which gave the results for the fruit without aeration and with aeration, respectively. Table IX summarizes the results of this experiment. The differences for the boxes aerated and those not aerated are greatest for the unwrapped apples, and in favor of aeration. This suggests the necessity for unwrapping apples in order properly to aerate them. As late as March 4, the common wraps aerated had more scald than the same not aerated, but the results were reversed when the apples were examined on January 15. An average of all of the apples shows little difference at each time of inspection. Of those apples aerated, the amount of scald as it appears on March 4 was proportional to the amount of aeration or permeability afforded by the wrap treatment, if we leave out of consideration the effect of the oil wraps in this connection. Likewise, the relationship was the same at the earlier period of examination, January 15, except that the positions of wax and tinfoil wraps were interchanged.

TABLE VII. PERCENTAGE OF GRIMES AFFECTED WITH SCALD. TREATMENT, VARYING KIND OF WRAP WITHOUT AERATION.

Wrap	Lot no.	No. of apples	Condition					
			January 15, 1922			March 4, 1922		
			Slight	Medium	Bad	Slight	Medium	Bad
Tissue	5	152	42.7	2.6	0.0	41.4	20.4	9.8
	6	138	1.4	0.0	0.0	5.8	2.1	0.0
	7	150	38.0	3.3	6.0	22.6	20.0	8.6
	8	138	39.8	5.0	2.9	36.2	18.8	14.5
	9	150	31.3	4.6	4.6	42.0	8.6	9.3
	10	142	40.8	2.8	0.0	42.9	15.5	12.7
	39	150	49.3	10.0	6.6	40.7	20.6	24.0
	40	129	48.1	7.7	3.8	47.3	24.8	15.5
No wrap	15	162	48.1	25.8	11.7	23.4	21.6	47.6
	16	136	31.6	0.0	0.0	31.6	8.0	20.6
	17	150	21.9	4.6	0.0	41.3	14.0	8.6
	18	158	36.7	8.8	0.0	35.4	16.4	13.9
Oil	23	150	10.0	0.6	0.0	20.6	1.3	0.0
	24	145	8.9	0.0	0.0	16.5	3.4	0.0
	25	138	21.7	0.0	0.0	13.2	6.5	0.0
	26	125	23.2	0.0	0.0	30.4	7.2	2.4
	31	142	17.6	0.0	0.0	24.6	4.9	0.0
	32	150	44.0	3.3	0.0	32.0	10.6	2.6
	35	141	19.8	3.5	0.0	26.2	3.5	2.8
	36	123	40.7	2.4	0.0	46.3	4.0	0.8
Wax	43	138	41.3	10.8	4.3	36.2	15.9	31.9
	44	138	42.7	17.3	6.5	27.5	26.5	24.6
Tinfoil	47	142	45.7	16.9	4.2	37.3	26.0	21.8
	48	149	38.6	4.0	1.3	30.9	23.5	26.2

TABLE VIII. PERCENTAGE OF GRIMES AFFECTED WITH SCALD. TREATMENT, VARYING KIND OF WRAP WITH AERATION.

Wrap	Lot no.	No. of apples	Condition					
			January 15, 1922			March 4, 1922		
			Slight	Medium	Bad	Slight	Medium	Bad
Tissue	1	162	19.2	0.6	0.6	37.6	11.7	17.9
	2	150	45.3	11.3	3.3	38.7	14.0	16.7
	3	132	19.7	0.7	0.0	34.8	7.5	9.8
	4	125	17.6	2.4	0.0	27.2	8.8	7.2
	37	150	26.0	0.6	0.0	52.0	10.6	9.3
	38	175	30.8	9.1	4.5	37.7	16.0	29.1
No wrap	11	150	8.0	0.0	0.0	26.7	5.3	4.6
	12	125	8.0	0.0	0.0	16.0	7.2	1.6
	13	150	24.6	1.3	0.0	47.3	10.6	9.3
	14	139	43.1	5.0	2.1	36.0	28.2	23.1
Oil	19	150	4.6	0.0	0.0	14.6	1.3	1.3
	20	150	12.0	2.6	0.6	24.0	6.0	2.6
	21	125	0.0	0.0	0.0	5.6	0.0	0.0
	22	138	14.5	0.7	0.0	19.5	2.9	2.1
	29	136	12.5	1.4	0.0	25.7	4.4	0.0
	30	150	18.0	1.3	0.0	27.3	5.3	0.6
	33	137	30.6	2.9	2.1	32.8	16.8	6.5
	34	125	31.2	0.0	0.0	32.8	13.6	0.0
Wax	41	125	44.8	11.2	2.4	37.6	25.6	23.2
	42	125	64.8	8.0	12.8	32.8	33.6	33.6
Tinfoil	45	125	56.8	8.8	1.6	40.0	25.6	24.8
	46	125	59.2	12.0	4.0	29.6	20.0	40.8

Experiments on aeration were followed out in the season 1922-23. A maturity and oiled wrap experiment was carried on at the same time in which parallel tests were made under the same conditions of picking and storing as for aeration. There were five picking dates for Grimes and three for Arkansas. The boxes picked on these dates were not stored at the same time. Of the four boxes picked for aeration, on a particular date; one was stored with its check box, at once; the second, a week later; the third, two weeks later and the fourth three weeks later. Whenever a box for the aeration test was placed in cold storage another check box, previously treated the same way, went into storage at the same time and under the same storage conditions except for aeration.

Table IV shows the results obtained in this experiment with Grimes. As far as aeration is concerned, its benefit was no-

TABLE IX. PERCENTAGE OF SCALD ON GRIMES AS AFFECTED BY VARIOUS WRAPS AND BY AERATION, 1921-1922.

Summary of tables VII and VIII.

Wrap	With aeration			Without aeration		
	No. apples	Jan. 15, '22	Mar. 4 '22	No. apples	Jan. 15, '22	Mar. 4 '22
Tissue	894 (6 bxs)	1.5	15.7	1149 (8 bxs)	3.0	11.8
No wrap	564 (4 bxs)	0.5	9.7	606 (4 bxs)	3.1	23.1
Oil	1111 (8 bxs)	0.3	1.7	1114 (8 bxs)	0.0	1.0
Wax	250 (2 bxs)	7.6	28.4	276 (2 bxs)	5.4	28.2
Tinfoil	250 (2 bxs)	2.8	32.8	291 (2 bxs)	2.7	24.0
	Average	1.5	12.0	**Average**	2.2	12.7

ticeable only on early picked apples. For the apples picked on September 16, the scald was considerably reduced due to aerating. However, for those picked at the mid-season date and after, practically no scald occurred either without aeration or with aeration. The conclusion in this case is that after a certain stage of maturity of the apple has been attained, there is little gained by employing aeration as a scald preventative.

With Arkansas in table V the results are not in agreement with those for Grimes. Scald developed under both conditions with respect to aeration. The inference in this case is that aeration was not beneficial either for early or for late picked fruit.

IMMEDIATE vs. DELAYED AERATION.

In the aeration work with the Rome Beauty variety, immediate aeration was compared with delayed aeration, during the cold storage period. In this case the apples were wrapped. Two lots were aerated for the first nine weeks, two for the first 14 weeks and two for the entire period of 28 weeks. Similarly, two lots were not aerated for the first 9 weeks, two not for the first 14 weeks, but aeration was given subsequently. Two lots not aerated for the entire period served as checks. These data may be seen in table X.

Still another experiment was carried on with the variety, in which the same scheme was carried out, but the apples were placed in standard boxes without wrapping. One box was used as a unit instead of two in this case. By referring to tables X and XI it will be seen that not much scald occurred under any of the treatments. For the apples which were wrapped the worst scald occurred where aeration was not given thruout the period of 28 weeks; while for the apples under aerated conditions for 28 weeks with otherwise corresponding treatments no scald made its appearance. This decidedly favors aeration.

The results in table XI show that little or no scald appeared in the unwrapped apples either aerated or not so treated. However, there was more scald on the wrapped specimens (table X) where aeration was delayed, and also where none was given, than for the unwrapped specimens. But when the apples were aerated at once, the differences were small for the amount of scald between wrapped and unwrapped boxes.

TABLE X. PERCENTAGE OF ROME APPLES AFFECTED WITH SCALD—TISSUE WRAPPED; STORAGE PERIOD 28 WEEKS—1921-22.

Aerated immediately					Aeration delayed				
No. apples	No. weeks aerated	Percentage of scald			No. apples	No. weeks delayed	Percentage of scald		
		Slight	Medium	Bad			Slight	Medium	Bad
326	9	2.1	0.3	0.0	324	9	0.3	0.0	0.0
338	14	1.4	0.5	0.3	326	14	0.3	1.2	0.9
252	28	0.0	0.0	0.0	333	*	3.3	3.0	21.0

*No aeration given.

TABLE XI. PERCENTAGE OF ROME APPLES AFFECTED WITH SCALD. UNWRAPPED; STORAGE PERIOD 28 WEEKS—1921-22.

Aerated immediately					Aeration delayed				
No. apples	No. weeks aerated	Percentage of scald			No. apples	No. weeks delayed	Percentage of scald		
		Slight	Medium	Bad			Slight	Medium	Bad
170	9	0.0	0.0	0.0	163	9	0.0	0.0	0.0
163	14	3.6	1.2	1.8	159	14	0.0	0.0	0.0
179	28	0.0	0.0	0.0	163	*	2.4	1.2	0.0

*No aeration given.

If we had used material which would have given wider ranges between results of the treatments, the results might have been more significant. In practically all comparisons made between aeration and without, there was a slight advantage in favor of the former. In regard to immediate and delayed aeration, the results can hardly be taken as conclusive. In general, aeration was beneficial.

A further experiment with the Rome Beauty variety was carried out during the same season. The plan and the results of this work are set forth in table XII.

The figures give the total number of scalded apples, regardless of the severity of the disease on a single specimen. The evidence given is in favor of aeration. Only on the apples which were not aerated has scald made its appearance. Oiled wraps controlled scald under both conditions, however.

INFLUENCE OF VARIOUS WRAPS ON SCALD DEVELOPMENT

The use of various kinds of wraps in connection with cold storage investigations of apples has been applied under a variety of conditions and with many varieties of apples. Powell and Fulton (9) were probably the first to carry on wrap experiments with apples in this country. Beach and Eustace (1) have pointed out that wrapping retards shriveling, reduces the amount of bruising and prevents decay. Brooks, Cooley and Fisher (4) have reported that ordinary apple wraps have had no effect on apple-scald and that paraffin wraps have had but little; but wraps soaked in mixtures of various oils have entirely prevented apple-scald. These same investigators in a later publication (6) reported that oiled wraps have furnished the most complete protection against scald. Whitehouse (12) has stated that wrapping apples in common tissue wraps has

TABLE XII. PERCENTAGE OF TOTAL SCALD ON ROME AS AFFECTED BY VARIOUS WRAPS AND BY AERATION, 1921-22.

Wrap	Aerated			Not aerated		
	No. apples	March 10 1922	May 10 1922	No. apples	March 10 1922	May 10 1922
Tissue	316	0.0	0.0	325	0.0	12.9
Oil	173	0.0	0.0	171	0.0	0.0
No wrap	154	0.0	0.0	171	0.0	1.7
Wax	143	0.0	0.0	150	0.0	2.6

Fig. 13. These Grimes were wrapped in wax wraps. They were removed from cold storage on March 4 and were badly scalded. This condition was typical also for Grimes wrapped in common paper, in tinfoil and for unwrapped apples.

delayed the appearance of scald and that a paraffin wrapper has retarded scald slightly more, but that this difference was of no practical significance.

In 1921-22 more data was acquired on apple wrap experiments, using the following kinds of wraps: common paper, paraffine paper, tinfoil and commercial oiled wraps. Apples unwrapped served as checks. Table IX summarizes these data. The least amount of scald occurred where the apples were wrapped in an oiled wrap, and the amount of scald present was not important from the commercial standpoint. Figs 13 and 14 show the condition of apples in regard to the amount of scald on March 4 for wax wraps and oil wraps, respectively. Tinfoil and wax seemed to be the least effective wraps, the apples having scalded about an equal amount in each case and very severely. The results obtained for common wraps was about the same for wax and tinfoil. The check boxes, which were unwrapped, scalded badly. This indicates that common wraps were not beneficial in controlling this storage malady.

A further test to observe the behavior of oiled wrapped apples as compared to unwrapped apples, after a period of time subsequent to removal from storage, was conducted. The apples selected were free from scald on March 2, which was the

time they were removed from cold storage. Apples which had scalded at this time were eliminated. The apples used came from the same orchard and were, as far as known, under comparable conditions of handling and storing. They were of a uniform shade of yellowish green in color when removed from cold storage. These apples were then placed in ordinary cellar storage. All apples were unwrapped, as the purpose of the test was to see if the effect of the oil would be apparent after the oiled paper was removed. The following data shows the outcome of the experiment on May 13. The apples were out of cold storage 72 days:

Treatment	No. of apples	Percentage of scald		
		Slight	Medium	Bad
Previously unwrapped	43	16.3	18.6	58.1
Previously oil wrapped Content of oil 18-20%	52	26.9	0.0	0.0
Previously oil wrapped Content of oil 17%	46	78.3	0.0	0.0
Previously oil wrapped Content of oil 5%	61	9.8	0.0	0.0

The results show that the effect of the oiled wraps was far-reaching and retarded scald development even when the wrap was taken away from the apple. This might have been due to the presence of a film of oil remaining on the apple after the removal of the wrap, sufficient to inhibit scald in the same

Fig. 14. These Grimes apples were wrapped in oiled wraps. They were removed from cold storage on March 4 and were free from scald. Compare with fig. 13.

manner as if the oiled wrap was present. Another supposition is that the respiratory processes within the apple were arrested or affected in such a manner by the oil as to prevent or delay the occurrence of scald.

During the season, 1922-23, still another experiment was carried out which shows the effect of commercial oiled wraps on scald development. Table IV presents this data for Grimes. It will be seen from the evidence available that oiled wraps were only an advantage with Iowa grown Grimes, when the apples were picked somewhat immature. It is to be regretted that the oiled wrap used in this case was somewhat low in oil, the content being only five percent. The results, nevertheless, were decidedly in favor of oil wrapping for the earlier picked fruit. The results for the first three lots might have been more striking had a wrap with a higher oil content been used. Over-mature Grimes are very liable to breakdown in storage, so that picking this variety slightly under a mature condition is desirable. In this case, the use of oiled wraps as a safeguard from severe scald is advisable. Other oiled wraps containing higher percentages of oil were used, but in these cases since no scald developed under any of the different treatments, (presumably due to the condition of maturity) no benefit from their use was discernible.

Table V, which has already been referred to under the aeration experiments, gives more data on the use of oil and oiled wraps on scald control for Arkansas apples. In this case, again, a wrap containing only five percent of oil, was used, which may account for the apparent ineffectiveness of the oiled wrap. It is interesting to note that in the lot which was smeared with oil, scald was very much reduced on the apples as compared to the other lots, in which the apples were wrapped in common paper, in oiled paper or were unwrapped. This suggests the possibility that a wrap with only a five percent saturation of oil is insufficient as a scald preventative.

SCALD AS OCCASIONED BY SOME ODOROUS SUBSTANCES.

Certain apple varieties have characteristic aromas and it is altogether possible for an expert to identify different varieties by their respective odors. Particularly are these aromas noticeable with apples under cold storage conditions. It is commonly accepted that these odors are due to the formation of esters and possibly other aromatic compounds. Text books on organic chemistry give the properties of esters as usually colorless, neutral, pleasant smelling liquids, sparingly soluble or insoluble in water; being generally formed when an alcohol is mixed with an acid. This change is a gradual one, and is never complete

because the reaction is reversible. It has been shown that alcohol always appears in intramolecular respiration of higher plants and often collects in considerable quantities. Brefeld (2) found ½ to 2 percent alcohol in grapes after several weeks, in cherries 1.8 to 2.5 percent in four weeks. Jost (8) states that not only ethyl alcohol is formed in intromolecular respiration of plants, but other higher alcohols, acids, aromatic compounds, esters and even hydrogen are given off, but as to their proportional amounts nothing is known.

Some preliminary experiments to determine the effect of certain esters and other volatile substances on Grimes and Jonathan under cold storage conditions were undertaken. The apples were supported at the top of large jars having a capacity of approximately 10 liters. A proportional amount of substance was added to each jar in the ratio of 2.6 cubic centimeters to 10 liters. An equal amount of water was added to lessen the rapidity of the rate of action of the substances upon the apples. The liquid was placed at the bottom of each jar which was loosely covered with a glass plate after inserting the apples. Five specimens each of Grimes and Jonathan were placed in the jars. These apples were free from any apparent disorders. The temperature of the room where the experiment was carried on was 34°F. Observations were made daily for 30 days. The final results were taken immediately upon removal of the apples from the cold storage room.

The results reported in table XIII do not always give typical scald where an ester or an acid and an ester are involved, the scalding usually being too severe to resemble scald as it occurs normally. The results with the aldehydes, particularly acetaldelyde, are interesting since Power and Chestnut (10) have reported this substance as one emanating from ripe fruit as determined by chemical analysis, and state "It is quite probable that the exhalation of acetaldehyde may prove to be one of the factors involved in the production of apple-scald." These investigators have found that the odorous constituents of apples consist of amyl esters of formic, acetic and caproic acids, with a very small amount of caprylic ester and a considerable proportion of acetaldehyde.

Another experiment showing the effect of ethyl acetate upon scald development and the protection afforded by the application of the oiled wrap was carried out. Two unwrapped Grimes apples were placed in each of seven 2-liter specimen jars. Another series of seven jars was used for the same number of oiled wrapped apples. Concentrated ethyl acetate varying in quantities of one-tenth cubic centimeter to six-tenths cubic centimeter was used in each of six jars, respectively. The seventh jar of each series served as a control. The results obtained ap-

TABLE XIII. EFFECT OF SOME VOLATILE SUBSTANCES UPON GRIMES AND JONATHAN.

Substances	Results
Ethyl alcohol 95%	Grimes and Jonathan all sound.
Ethyl alcohol 90% Acetic acid 10%	One Grimes apple slightly scalded. One Jonathan apple slightly spotted. Others sound.
Acetic Acid	All Grimes deeply browned into flesh. Trouble developed in ten hours. Not typical scald for Grimes. First scald on Jonathan appeared in 24 hours. Too severe to resemble typical scald.
Water	One Grimes slightly scalded, other specimens sound. Slight cases of Jonathan-spot on all specimens, except on poorly colored ones.
Ethyl alcohol 50% Acetic acid 50%	Skin on Grimes severely browned in patches to the depth of core in some cases. Not typical scald. On Jonathan cases of deep scald developed similar to that on Grimes.
Ethyl alcohol 80%	On Grimes, slight scald developed in 3 weeks.
Amyl acetate 20%	One apple failed to develop typical scald. Jonathan remained in excellent condition.
Ethyl alcohol 95% Amyl acetate 5%	Slight amount of scald on two Grimes apples, other specimens free from scald. Some Jonathan-spot ranging from slight to medium in severity.
Ethyl alcohol 95% Ethyl acetate 5%	All specimens of Grimes in good condition. One specimen of Jonathan badly spotted, others with medium degree of spot.
Formaldehyde	Severe browning on Grimes and discoloration to the core. Same result occurred with Jonathan.
Formaldehyde 10% Water 90%	Typical scald on Grimes, ranging from the bad degree to slight. Jonathan, free from scald, but all had developed Jonathan-spot.
Acetaldehyde	Deep scald on Grimes with flesh browning varying to slight browning of the skin. Four Jonathan affected with deep scald, the other developed Jonathan-spot.
Acetalydehyde 10% Water 90%	Some slight scald on Grimes. Three specimens sound. Some slight scald and Jonathan-spot on Jonathan.
Acetaldehyde 10% Ethyl alcohol 90%	All Grimes apples sound. All Jonathan apples sound.
Ethyl acetate 20% Ethyl alcohol 80%	All Grimes free from scald. Jonathan, 3 with deep scald. Some Jonathan-spot occurred.
Formaldehyle 10% Ethyl alcohol 90%	Grimes; deep browning, ranging in severity from a discoloration of the flesh to a slight skin discoloration. Jonathan—Deep browning in patches affecting all specimens—Jonathan-spot on all specimens.
Ether	Grimes in good condition. Slight spot on one specimen. Jonathan slight spot in all cases.

pear in table XIV and were taken at the conclusion of the experiment.

The data given show that the oiled wrap used had considerable influence in preventing and retarding the appearance of artificial scald as caused by ethyl acetate.

AERATION EXPERIMENT WITH ETHYL ACETATE.

Five Grimes apples were placed in each of three bell jars which could be hermetically sealed. These apples were a light shade of green in color and were free from scald. The experiment was carried on at a temperature of 34°F. in a cold storage room having a relative humidity of 80 percent. One jar remained closed and served as as check. In each of two jars was placed 10 c.c. of ethyl acetate in specific gravity bottles having an opening with a diameter of 7.7 milimeters. One jar was

aerated continuously with the storage room air. In the other two jars there was no renewal of air within the jars.

Artificial scald, resembling typical apple scald, appeared in both jars with ethyl acetate in seven days, but was less marked where aeration was given. Thirty days later the following notes were taken:

Jar, not aerated—Apples firm, badly browned on the surface and to the core. Odor, that of ethyl acetate; 5.3 c.c. acetate remained.

Jar, aerated—No browning or scald, other than appeared at the end of seven days. This was slight and hardly noticeable; 4 c.c. acetate remained.

Jar, without acetate—No scald appeared at any time.

We conclude that ethyl acetate under certain conditions causes artificial scald; that aeration in the presence of ethyl acetate is influential in decreasing the amount of scald or preventing its occurrence.

DISCUSSION OF EXPERIMENTS ON APPLE-SCALD.

Experiments comparing the amount of apple-scald on Grimes grown under different soil treatments show little differences over four seasons. The treatments consisting of clover and bluegrass sods, clean tillage, and cover crops did not give wide differences in the amount of scald, but generally there was a noticeably smaller amount of scald on the fruit from the bluegrass plot. Harvest records showed that the Grimes from this plot color earlier and ripen earlier than from the others. The effect

TABLE XIV. INFLUENCE OF OILED WRAPS ON SCALD DEVELOPMENT WHEN APPLES ARE EXPOSED TO ETHYL ACETATE VAPORS.

C.C. ethyl acetate used	Unwrapped apples		Wrapped apples	
	Initial appearance of scald	Description and final appearance in 14 days	Initial appearance of scald	Description and final appearance in 35 days
Control	.....	No scald—14 days	.....	No scald.
1/10	4 days	Injury resembles scald; apples firm; color that of severe scald; appeared in patches.	.....	No scald.
2/10	4 days	Apples scalded over entire surface; still firm.	.....	No scald.
3/10	2 days	Apples scalded; one specimen entirely brown; other, 75 percent colored; firm.	.....	No scald.
4/10	2 days	Apples all brown with scald except near basin of one specimen; slight softening of flesh was noticeable.	5 days	One apple had about 20 percent of surface scalded; somewhat soft; upper apple free from scald.
5/10	1 day	Specimens brown over entire surface. Slightly soft, but not extending deeply into flesh.	.....	No scald.
6/10	1 day	Specimens appear the same as those for 5/10 c.c.	5 days	Lower apple nearest ester entirely scalded. Upper apple sound.

of the maturity of the fruit on scald development and control has been emphasized in these experiments.

Maturity experiments which consisted of picking at different intervals and storing at regular weekly intervals, showed over a period of three seasons that apple-scald depends largely on the maturity of the fruit when stored. In 1920-21 and 1922-23, with extra fancy pack, uniformly sized, the rather immature Grimes scalded badly, while those picked quite late were practically immune to scald. The results for 1919-20 did not check as well, but rather showed about as much scald on the late picked fruit as the early picked. The results for this season were not exactly comparable to those of the other two seasons as the experimental fruit in 1919 consisted of orchard run material, of mixed sizes which could have included undercolored and immature specimens in each box. Delayed storage in 1919 did not appear to be beneficial, but for 1920-21 and 1922-23, delaying the storage period of the earlier picked fruit usually decreased the amount of scald in proportion to the length of delay. Arkansas, likewise in the latter season, had a lesser amount of scald than the earlier pickings. A 10-day delayed storage decreased the amount of scald 42 percent in one lot over another similarly treated lot, stored immediately.

From these experiments, it is evident that determining the exact maturity of the fruit at the orchard is of great importance. Experiments giving data on this point are very desirable.

Experiments indicated that aeration as a scald preventive method for Grimes cannot be considered reliable. The experiments which were conducted along with the maturity tests showed that maturity is far more important in affecting scald development than aeration. It was evident that only the apples in a rather immature condition when stored were benefited by aeration, if benefited at all. Tests with Grimes in 1922-23 showed aeration to be of considerable advantage in reducing scald on the earlier picked fruit, but not for Arkansas. In 1919, 1920 and 1921 with Grimes, these advantages were not very marked. In one season, unwrapped fruit showed the widest margin of differences in favor of aeration compared with unaerated conditions. This suggests that apples should be left unwrapped in order to properly aerate them.

Experiments with Rome variety, where immediate and delayed aeration were compared during the cold storage period, results were not sufficiently different to be conclusive. Between two lots where one was aerated thruout the entire season and the other given no aeration, there was a distinct advantage in favor of the aerated lot. In still another experiment in which various wrap treatments under both aerated and

unaerated conditions was considered, it was found that aeration prevented scald for all wrap treatments; in unaerated conditions, scald made its appearance for all except the oiled wrap lot. It may be concluded, in general, that aeration was beneficial in reducing scald on this variety.

Oiled wraps were found to be far more effective as a scald preventative than aeration, but only apples in an immature condition responded to this treatment. The oiled wrap experiments, which were conducted with Iowa grown fruit, were run parallel with a maturity experiment of oiled wraps and common wraps. The Grimes, picked and stored in the less mature condition, scalded considerably less in oiled wraps than in common wraps. However, with a certain stage of maturity, this variety did not scald under either the common or the oiled wrap treatments. In another oiled wrap experiment with Washington grown Grimes where maturity conditions varied, but where there was no classification of exact maturity, it was found that oiled wraps controlled scald in all cases from a commercial standpoint. Since oiled wraps do insure a decrease in apple-scald if the fruit is stored in a rather immature condition, and since it is difficult to determine just the critical point in the stage of maturity, the oiled wrap is of value for reducing this storage trouble. This is particularly true for a variety such as Grimes, because when this variety is stored in an over-mature condition its life in storage is usually shortened because of internal breakdown. Therefore, in the storage of this variety there is no safe margin of either under-maturity or over-maturity. Oiled wraps do increase the margin of under-maturity and are, therefore, of considerable value. Better results were obtained with an oiled wrap, having an oil content of 15 percent, than with one having only five percent. Apples scalded worse in wraps and in tinfoil wraps than with common wraps, or apples unwrapped. This suggests the relation of apple-scald to the permeability which the wraps afford to the products of respiration of the apple.

Artificial apple-scald can be quickly produced on apples by exposing them for short periods to the vapors of such volatile substances as ethyl acetate, amyl acetate, acetaldehyde and acetic acid. The severity of browning in each case is conditioned by the amount of liquids used and by the length of exposure. In an experiment with Grimes, one lot was wrapped in oiled wraps and one was left unwrapped. It was found that ethyl acetate, in various proportions, caused artificial scald on the unwrapped apples, but no scald occurred with the oiled wrapped apples over a considerable period. After 35 days, only two cases out of six showed any scald on the oiled wrapped apples, and these were in the denser atmospheres. In another ex-

periment, it was found by aerating the container in which apples were exposed to ethyl acetate the amount of scald was markedly reduced.

INTERNAL BREAKDOWN.

Internal breakdown, or physiological decay, has appeared frequently with Iowa grown Grimes under cold storage conditions, but much less frequently upon Jonathan. By breakdown is meant the physiological decay accompanied with internal browning which occurs at the end of the life of the fruit. The time of appearance of this trouble is readily influenced by the maturity of the fruit when stored, and by the temperature under which it is stored. Varieties such as Grimes, Jonathan and King David are more susceptible to breakdown than Winesap Arkansas and similar varieties.

Breakdown on Grimes may manifest itself as mealiness of the flesh, accompanied with a partial browning of the flesh and skin. Often this condition is followed with bursting of the skin. Frequently, breakdown may be present and not easily seen because of no skin discoloration. It can then be detected by a dull appearance of the skin. In such cases a slight pressure on the apple reveals a softening from within. Since the earlier stages may not easily be noticed, there is a possibility of controversies resulting when fruit so affected is sold on the market. In cross section the apple shows a distinct core of soft, brown flesh. This may occur as a small spot or may extend partially around the apple entirely beneath the skin. In the latter stages, however, this internal softening may extend in a circular core within the apple, part way between the core and the skin. In advanced stages the disease involves the entire apple. In other cases, the breakdown occurs in contact with the skin when external browning is evident. Where only internal browning is present there is a layer of uncolored sound flesh immediately beneath the skin of the apple. On some Grimes we may have both types of internal breakdown. These two types of breakdown may be seen in figs. 15 and 16. Where the breakdown is toward the outer surface of the apple and shows a distinct skin discoloration, usually there is no mealiness of the flesh noticeable, but the affected part is moist and somewhat viscous, as contrasted to the mealy type of breakdown where the flesh is dry and crumbling in nature. Whether the two types of breakdown should be recognized as distinct and treated separately is difficult to determine. But there seems to be differences between the two, as often only one type is present in a certain lot of apples, while the other type will pre-

Fig. 15. Breakdown on Grimes. This is the usual type of breakdown occurring on Grimes. Note there is a sound layer of uncolored flesh between the skin and discolored portions in each specimen.

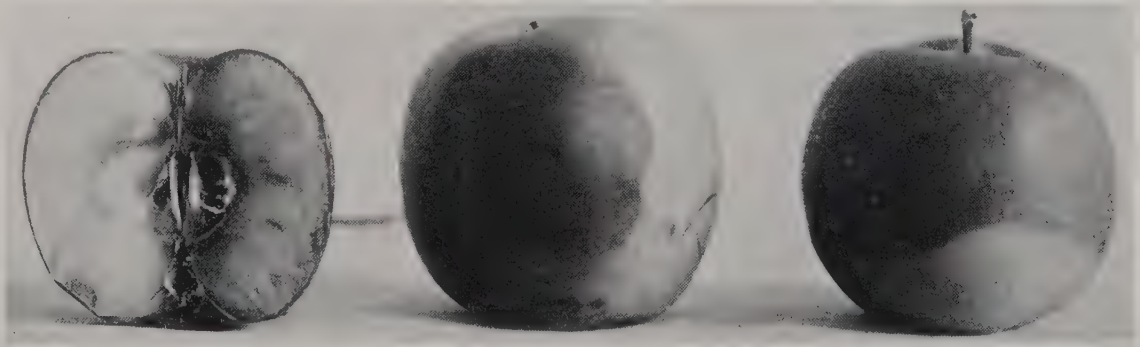

Fig. 16. A type of breakdown commonly found on Grimes. This discoloration in this case usually extends to the skin of the apple.

dominate in another lot. While this usually is true, it was noticed that occasionally the two types occur within the same lot. Just what conditions favor development of one kind of breakdown over the other was not definitely determined. More observations on this point are desirable.

EFFECT OF MATURITY ON INTERNAL BREAKDOWN.

The results for internal breakdown on Grimes as observed for the season 1919-20 are given in table XV. The evidence was in favor of early picking, altho not in favor of immediate storing. Why immediate storage showed more breakdown than delayed storage is not easy to explain. The results, however, were not exactly comparable with those of subsequent seasons because orchard run material was used and the variable maturity of the apples may have caused the difference.

No internal breakdown occurred on Jonathan at any time during 1919 when observations were made.

Table XVI shows the outcome of the treatments with Grimes for 1920-21. Figs 11 and 12 show these results graphically with respect to breakdown. Less breakdown is shown in fig. 11 on apples picked from September 14 to September 24 than in fig. 12 on those picked from September 28 to October 5. No breakdown occurred on the apples in the lot picked on September 24, and the greatest amount occurred on October 2, with about the same amount for each treatment of delayed storage. From the results of the two years it appears that time of picking is more important than time of storing. Delayed storage did not con-

TABLE XV. PERCENTAGE OF INTERNAL BREAKDOWN ON GRIMES. TREATMENT, VARYING PICKING DATE AND DELAYING STORAGE PERIOD. 1919-20.

Lot. no.	No. of apples	No. days delayed	Condition	
			Feb. 11	March 30
Apples picked Sept. 23.				
1	163	1	0.0	0.0
2	150	8	0.0	12.5
3	175	15	0.0	0.0
4	175	22	0.0	0.0
Apples picked Sept. 27.				
5	187	1	8.0	13.9
6	185	8	57.8	77.5
7	182	15	0.0	0.0
8	186	22	0.0	0.0
Apples picked Oct. 2.				
9	164	1	64.7	68.4
10	176	8	17.1	24.4
11	181	15	0.0	0.0
12	203	22	0.4	2.4
Apples picked Oct. 7.				
13	163	1	6.1	36.2
14	153	8	13.0	32.6
15	165	15	7.2	9.7
16	165	22	8.4	17.0

TABLE XVI. PERCENTAGE OF INTERNAL BREAKDOWN ON GRIMES. TREATMENT, VARYING PICKING DATE AND DELAYING STORAGE SEASON. 1920-21.

Lot. no.	No. of apples	No. days delayed	Condition	
			Jan. 25	March 24
Apples picked Sept. 14.				
1	180	1	0.0	3.3
2	198	8	0.0	3.5
3	197	15	30.0	30.4
4	150	22	1.3	2.6
Apples picked Sept. 20.				
5	163	1	0.0	4.2
6	175	8	10.3	10.3
7	148	15	0.0	2.0
8	165	22	6.6	12.1
Apples picked Sept. 24.				
9	142	1	0.0	0.0
10	175	8	0.0	0.0
11	150	15	0.0	4.6
12	174	22	0.0	0.5
Apples picked Sept. 28.				
13	139	1	12.9	30.9
14	150	8	35.3	46.0
15	175	15	1.7	3.9
16	125	22	4.0	5.6
Apples picked Oct. 2.				
17	163	1	25.2	49.1
18	176	8	21.0	30.1
19	150	15	22.6	31.3
20	143	22	25.1	5.5
Apples picked Oct. 5.				
21	188	1	13.8	39.3
22	125	8	24.8	32.8
23	150	15	3.3	8.6
24	175	22	4.0	8.5

sistently give more breakdown, altho, in some cases more appeared to result as the cause of storing later.

In 1922-23, the amount of breakdown as affected by maturity, aeration and oiled wraps was considered. Table XVII shows these results. Only one examination was made.

No breakdown occurred in the case where the apples were picked early and stored immediately. Considerable breakdown became noticeable when picking was done early and storage delayed two or three weeks. The apples picked on September 20 (which happens to be the mid-season picking date for this experiment), when stored at once, did not break down. But when these same apples were delayed two weeks, considerable breakdown occurred. When delayed three weeks, in one box, the breakdown was as high as 35 percent.

Breakdown may be very severe in a box of apples even if stored immediately, but picked late; or it may be abundant if the apples are stored late, but picked early. Breakdown may or may not occur when apples are picked very mature and stored late, but the chances for its occurrence increase with late picking or with late storing. This is brought out in a comparison of lots 14 and 18. The apples were picked on September 25 and 30, respectively, and then delayed 22 days. In each lot,

TABLE XVII. RELATION OF MATURITY TO BREAKDOWN ON GRIMES—WITH AND WITHOUT AERATION—WITH COMMON AND OILED WRAPS. 1922-23.

Apples examined March 10.

Lot no.	Date of picking	No. days delayed	No. of apples	Percentage of breakdown in boxes				
				Date inspected	Without aeration		With aeration	
					Common wraps	Oiled wraps	Common wraps	Oiled wraps
1	Sept. 12	0	388	Mar. 26	0.0	0.0	...	...
2	"	0	351	"	0.0	0.0	...	...
3	Sept. 16	1	576	Mar. 8	0.0	0.0	0.0	0.0
4	"	8	739	"	0.0	0.0	0.0	0.0
5	"	15	752	"	2.1	5.7	45.2	18.1
6	"	22	738	"	9.3	55.5	1.6	57.0
7	Sept. 20	1	501	Mar. 8	0.0	0.0	0.0	...
8	"	8	493	"	0.0	1.3	1.1	...
9	"	15	539	"	10.1	18.6	5.5	...
10	"	22	551	"	16.5	21.1	35.6	...
11	Sept. 25	1	588	Mar. 8	0.0	0.6	36.6	4.8
12	"	8	688	"	0.0	2.8	2.8	6.0
13	"	15	688	"	12.0	20.2	27.4	30.0
14	"	22	739	"	0.0	2.1	1.0	18.3
15	Sept. 30	1	426	Mar. 8	4.0	0.7	1.8	...
16	"	8	439	"	12.8	8.7	9.4	...
17	"	15	476	"	0.5	0.0	0.7	...
18	"	22	489	"	2.4	0.0	1.2	...

one box contained no breakdown, but the other boxes all had a certain amount.

A comparison of the amount of breakdown occurring for the four seasons during which it was under observation is given in the following table:

TABLE XVIII. PERCENTAGE OF PHYSIOLOGICAL BREAKDOWN.

Variety	Season 1919-20 Examined Feb. 11	Season 1920-21 Examined Jan. 25	Season 1921-22 Examined Jan. 15	Season 1922-23 Examined March 10
Grimes	11.4	10.0	0.5*	8.5
Jonathan	0.4	0.0	6.2*	0.0

*The Grimes and Jonathan used in 1921-22 were western grown.

The table gives data based upon the average amount of breakdown present in the total number of boxes of apples for each season.

About the same amount of breakdown was present each season for Grimes when they were Iowa grown. Not much occurred on the western grown Grimes.

INTERNAL BREAKDOWN UNDER AERATED CONDITIONS WITH VARIOUS WRAP TREATMENTS.

Observations on the effect of aeration on internal breakdown were taken in 1920-21, but no definite control for breakdown resulted. The experiment in 1921-22, with western grown Grimes,

gave no conclusive results on the effect of aeration or of various wrap treatments for control of internal breakdown.

Table XVII shows there is no consistent evidence that oiled wraps affected the occurrence of breakdown; neither do the data give evidence that aeration prevented or affected the amount of breakdown.

Less breakdown occurred when the fruit was wrapped in wax or in tinfoil wraps, but the differences noted might have been attributable to maturity conditions. The worst breakdown occurred with unwrapped apples when not aerated, but since it was not possible to learn all of the conditions to which the various lots of western grown apples were subjected before storing, it is difficult to assign responsibility to one factor for the amount of breakdown.

DISCUSSION OF EXPERIMENTS ON INTERNAL BREAKDOWN.

While internal breakdown is not always a serious disease under cold storage conditions, it was observed in experiments to be of considerable consequence under certain storage conditions. In some years it becomes a factor before the end of the normal storage season of Grimes. Under some of the conditions of the experiments, internal breakdown was found to be more important as a storage trouble than apple-scald.

The results of the experiments for three seasons generally have shown that the chance for internal breakdown increases with late picking or with late storing. Breakdown, then, is the result of over-maturity which may be brought about in various ways. Late picking with immediate storing is often comparable to early picking with late storing in the amount of breakdown. Doubtless, breakdown can best be controlled by avoiding very late picking and by storing the fruit soon after it is picked.

Grimes apples held later than the first of January often become very susceptible to internal breakdown. Occurrence of this storage disease often may be avoided by not holding this variety too long in storage. The results indicate that Grimes should not be held later than the first of January.

It should be remembered that fruit stored rather immaturely may scald and at just what time Grimes should be picked and stored to secure a minima of both scald and breakdown is not easy to determine at the orchard. Perhaps the best solution is to pick this variety only slightly immature, that is, when the very first change in color of the skin from a green to a ripe yellow takes place; then wrap in an oiled wrap as a precaution against scald. With barreled apples, the condition of maturity must be relied upon entirely, since in this case it is not practical

to wrap the fruit in oiled paper and since aeration gives such unreliable results as a preventive of apple scald.

A comparison of the results, showing the amount of internal breakdown occurring with apples in oiled wraps and with apples in common wraps, gave no consistent evidence that oiled wraps reduced the amount of breakdown. Likewise, no definite control of breakdown resulted in the application of aeration.

RATE OF TEMPERATURE CHANGES IN BOXED APPLES.

Whitehouse (12) has shown that it required 30 hours to reduce the temperature of wrapped boxed apples from 70° to 40°F. An experiment was carried on in a similar manner on Grimes apples, wrapped and unwrapped. The purpose of the experiment was to show comparisons in the rate of decrease and increase in temperature as affected by the various wrap treatments. Metal resistance thermographs were used and placed at the center of the boxes. The temperature of the cold storage room was maintained at 32°F. and that of the warm room approximated 70°F. The boxes were shifted from the cool room to the warm room and vice versa.

TABLE XIX. NUMBER OF HOURS REQUIRED TO CHANGE THE TEMPERATURE OF BOXED APPLES.

Kind of wrap	From 60° to 34°F.	From 34° to 68°F.
Common	63	37.5
Common (with aeration)	57	....
Unwrapped	59	18.5
Oiled	57.5	42
Tinfoil	42	31

The data in table XIX need little discussion. Common wraps slowed up the rate of cooling of apples the most and tinfoil the least. The differences in the rate of cooling between unwrapped, oiled wrapped and common wrapped apples were not very great and are probably of no commercial significance. The rate of increase in temperature of apples when the cold apples were placed in a large warm room is faster than the rate of cooling in a small room within the same range of temperature. In this case, unwrapped apples increased up to 68°F. in about one-half the time it took the common wrapped apples. Apples in oiled wraps warmed up slowest. Apples in tinfoil warmed up to 68° from 34°F. in six and one-half hours sooner than apples in common wraps, but twelve and one-half hours slower than unwrapped apples. Aeration did not greatly influence the rate of cooling of wrapped apples.

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